



Potential Strategy for Implementing Co- Development Opportunities

August 2022

Changing the World's Energy Future

William Dunkley Jenson, Robby Anthony Joseph



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

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Spent Fuel and Waste Disposition

***Prepared for
U.S. Department of Energy
Office of Integrated Waste
Management***

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August 31, 2022

**PICS:NE Milestone No. M4IS-22PN0402057
National Laboratory Report No. PNNL-33264**

**SFWD Working Document: External Release
or Reference Requires DOE-NE Approval**

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This is a technical report that does not take into account contractual limitations or obligations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment.

To the extent discussions or recommendations in this report conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this report in no manner supersedes, overrides, or amends the Standard Contract.

This report reflects technical work which could support future decision making by the U.S. Department of Energy (Department or DOE). No inferences should be drawn from this report regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

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ACRONYMS

BHP	Boulder Housing Partners
CEQ	Council on Environmental Quality
CISF	consolidated interim storage facility
CO ₂	carbon dioxide
DOE	U.S. Department of Energy
DOE-NE	U.S. Department of Energy Office of Nuclear Energy
EEIO	environmentally extended input-output
EERE	Office of Energy Efficiency and Renewable Energy
EJ	environmental justice
ESCO	energy service company
EV	electric vehicle
GDP	gross domestic product
IWM	Integrated Waste Management
Kg	kilogram
kW	kilowatt
kWh	kilowatt hour
LED	light-emitting diode
LITE	land-area identification, tagging, and exploration
M4	Milestone Level-4
MW	megawatt
NGO	non-governmental organization
NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory
PV	photovoltaic
R&D	research and development
RFI	request for information
SAM	System Advisor Model
SETO	Solar Energy Technologies Office
SMR	small modular reactor
SNF	spent nuclear fuel
SNL	Sandia National Laboratory
STEM	science, technology, engineering, and math
STP	science and technology park

SS&TP

Sandia Science and Technology Park

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ASSOCIATED SITING SUPPORT TOOLS DEVELOPMENT POTENTIAL STRATEGY FOR IMPLEMENTING CO- DEVELOPMENT OPPORTUNITIES

1. INTRODUCTION

This report documents work performed in support of the U.S. Department of Energy (DOE), Office of Nuclear Energy (DOE-NE) under work breakdown structure element 1.09.04.01, “Consent-Based Siting.” by Pacific Northwest National Laboratory and Idaho National Laboratory. It fulfills the Milestone Level-4 (M4) M4IS-22PN0402057, “report presenting a potential strategy for implementing the Multi-Mission Center concept,” within work package IS-22PN01040205, “Siting Tools Development-PNNL.”

DOE-NE’s Integrated Waste Management (IWM) Program is developing a community-consent-based process for siting a federal consolidated interim storage facility (CISF) for spent nuclear fuel (SNF). Key to this consent-based process is creating incentives for communities that might volunteer to host a CISF. DOE-NE’s approach, initially called “Multi-Mission Centers,” is to promote or facilitate other development projects in addition to a CISF that would provide host communities with additional economic opportunities or other benefits. Because each potential host community must be able to define the types of development that fit their interests and priorities, we recommend referring to this concept with the broader label “co-development opportunities.” Efforts under the Associated Siting Tools work package include assisting DOE-NE in developing a strategy for implementing co-development opportunities.

Activities in this work package are focused on refining the co-development opportunities concept described below in Section 2. This involves identifying a broad array of potential opportunities that may be of interest to communities depending on their interests and priorities and assessing potential siting considerations. Such considerations include benefits, adverse effects, barriers and constraints, and opportunities; these are discussed in Section 3. The recommended strategies to support and implement the co-development opportunities concept are discussed in Section 4.

This work is guided by recommendations from a previous feasibility study (Smith et al. 2021) and comments provided in responses to DOE’s 2021 request for information (RFI; DOE 2022). It has been coordinated with and informed by parallel activities supporting communications, stakeholder engagement, social sciences and environmental justice analyses, and other associated siting tools development.

2. CO-DEVELOPMENT OPPORTUNITIES CONCEPT

The objective of the co-development opportunities concept is to provide incentives to potential volunteer CISF host communities in the form of additional economic opportunities or other benefits. Such incentives may be an effective way to increase community interest and address stakeholder^a concerns, offset potential adverse effects of hosting a CISF, and support other interests and priorities. Oughton and Hansson (2013) reason that prioritizing the community’s goals in identifying compensatory measures

^a In this document a community is defined as an entity (or entities) that make a collective consent-based decision, and a stakeholder is an affected party within a community, or within a larger geographic area, whose interests and/or rights must be represented and considered.

could be seen as part of procedural justice—a concept arguably integral to a consent-based siting process in its emphasis on fairness and inclusiveness. While it is important to tailor the co-development opportunities concept to match the interests of individual communities, DOE-NE may determine it needs to structure the incentive opportunities in a manner consistent with and supportive of DOE (or potentially other federal agency) mission objectives, beyond the objective of siting a CISF. In applying such criteria, the extent to which they might reduce the incentivizing value of the opportunity should be evaluated.

The following sections discuss relevant considerations in support of specific strategy recommendations provided in Section 4.

2.1 Stakeholder Perspectives on Incentives

In December 2021, DOE-NE issued an RFI titled “Using a Consent-Based Siting Process to Identify Federal Interim Storage Facilities” asking for public input on multiple aspects of developing a consent-based siting process including an integrated waste management system and considerations related to providing incentives (86 FR 68244). The RFI included the following questions relevant to the co-development opportunities concept:

- “What benefits or opportunities could encourage local, State, and Tribal governments to consider engaging with the Department as it works to identify federal interim storage sites?”
- “What are possible benefits or drawbacks to co-locating multiple facilities within the waste management system or co-locating waste management facilities with manufacturing facilities, research and development infrastructure, or clean energy technologies?”

Responses to these questions are available in full in DOE^b (2022). In summary, several themes emerged:

- In general, commenters indicated that it is important that a potential host community define which co-development opportunities would be relevant or of interest to it as an incentive.
- Support for co-development opportunities came from a broad cross-section of commenters who suggested that DOE
 - prioritize opportunities that provide durable economic benefits, high-paying permanent jobs, and increased community support for hosting a CISF; and
 - consider a variety of opportunity types, including industrial, research and development (R&D), manufacturing, reprocessing, advanced nuclear technology, cask packaging, and supply chain-related development.
- Opposition to offering incentives was based largely on the concern that underserved and overburdened communities (e.g., low-income, communities of color, or linguistically isolated communities) could be “bribed” into hosting a CISF in return for potential benefits.

The comments show a discrepancy between those who view co-development opportunities as a positive means of supporting host communities and those who see the concept as an unfair means of influencing a community to host a CISF when it may not be in the community’s best interests or the best interests of some of its stakeholders. An article discussing the concept of “Free, Prior, and Informed Consent,” which the United Nations has declared a human right for Indigenous communities, defines one aspect of “free” consent as being “absent of coercion, intimidation or manipulation...[and a] process [that] is free from

^b <https://www.energy.gov/sites/default/files/2022-06/Responses%20to%20RFI%20on%20Consent-Based%20Siting%20and%20Interim%20Storage%20Updated.pdf>

coercion, bias, conditions, bribery or rewards” (Ibabao et al. 2013, p. 53). To avoid misunderstandings, DOE should develop a clear, consistent message conveying its intent to maximize benefits and minimize harm (rather than just providing compensation for harms) in part by providing incentives and compensation rather than bribes.

Such clear messaging might be informed by a law review article that assessed public concerns with the siting process of the Monitored Retrievable Storage facility for spent nuclear fuel on tribal lands in New Mexico (Sachs 1996). The article found that the most frequently made argument against the project related to bribery of a low-income community. Nevertheless, the article assessed this as the weakest of the oppositional arguments. Sachs points out that the alternative to a voluntary siting process with incentives is a compulsory decide-announce-defend siting process. Sachs also stated that if a community decides the benefits outweigh the drawbacks, arguments that developing the site is inequitable undermine the community’s opportunities to improve its welfare, and he shares that tribal leadership themselves pointed out that this argument is paternalistic. Finally, the Nuclear Waste Policy Act emphasized the importance of procedural fairness and trust in the siting process, which incentives can facilitate. Sachs points to a conundrum that existing distributional inequities in wealth in the United States do, in fact, lead low-income communities to volunteer to site facilities more readily. Sachs believes this concern can be alleviated by ensuring that safety and technical standards are optimized so that a community is not being bribed to take risks it would not otherwise. There are two exceptions: when a community is so underserved that it cannot make a free choice and when a community does not have enough information to make an informed choice (Sachs 1996).

Furthermore, in their article on nuclear waste facility siting, Hannis and Rawls point out that if a community perceives compensation as bribery, it can increase opposition (2013). However, the differences among compensation, bribery, and incentives are difficult to determine. An incentive seeks to change behavior, but to be appropriate should not lead to unethical or illegal behavior. However, an incentive could be unethical if the person agreeing to it accepts risks on someone else’s behalf. Hannis and Rawls argue that compensation does not persuade someone to change their behavior, and they conclude that for an incentive or reward not to serve as a bribe, there should be reasons for the site selection (e.g., geological, geographic) independent of the compensation or incentives offered. According to the authors, these criteria should be decided using a pluralistic process of public deliberation with potential host communities. If there are solid grounds for site selection, the reward is more likely to be seen as compensation rather than bribery.

Another factor that may determine how stakeholders perceive co-development is the timing of announcing the opportunity. Hannis and Rawls (2013) suggest that compensation is typically offered after the fact, while a bribe is made in advance; however, incentives are usually provided in advance but are not always viewed as a bribe. Further, withholding rewards until the end of the process conflicts with the goals of engaging a community early. It is possible that if the co-development concept is presented during the early phases of the consent-based siting process, it might be construed as a universally available form of compensation for host communities. Conversely, if it is announced later in the process, it may be negatively perceived as a tactic used to influence stakeholders to help DOE-NE achieve its objectives.

Sweden used a shared compensation approach that may influence the perception of co-development as compensation for both a host community and for process participants and not as a bribe. The “Value Added Program” shared compensation between two finalist potential host communities at the municipalities’ request. The site that was not selected received 75% of the total compensation (Kari, Kojo, and Lehtonen 2021). An approach which compensates non-selected sites recognizes that those not selected will likely not receive benefits from a CISF such as increased jobs and revenue (although they added to the process), while the selected host community is likely to receive these benefits.

Ultimately, multiple factors influence whether co-development opportunities are perceived as compensation for a community or bribes to unfairly influence a decision. These factors should be

carefully studied so that the process can be structured in a fair and equitable manner, and so that participants have the information and support needed to freely make decisions.

2.2 Defining Opportunities and Benefits

Each community has a unique set of values and needs that determine its interests and priorities for the future and help define what constitutes an opportunity or benefit for its stakeholders. For example, as evidenced from public comments shared in DOE (2022), some communities are interested in increasing (or in preventing decline of) the number of local jobs and the associated income and tax revenue streams. These growth-oriented communities may be most interested in opportunities that create new jobs, either for existing residents or for in-migrating workers. They may value jobs created by new manufacturing or production facilities, or they may favor potentially higher paying jobs created by R&D centers, educational institutions, or government facilities or offices. They may welcome the development or enhancement of infrastructure (e.g., roadways, railways, utility services) needed to support new development on the basis that those improvements may promote other industrial or commercial growth.

Alternatively, some communities may be averse to such growth and more interested in opportunities that would reduce existing financial, environmental, or social burdens or better position the community for the future. These communities might be more interested in investments that resolve local infrastructure issues, improve utility services, or promote greater energy independence. They might be interested in environmentally focused projects that address legacy contamination, restore degraded ecological systems, or protect land with cultural, recreational, or scenic values. Or they might be interested in construction of or upgrades to facilities, such as schools or medical centers, that improve or enhance citizens' quality of life or health.

Many co-development opportunities can be structured in a way that directly benefits the IWM Program or broader DOE-NE missions. Alternatively, or in addition, some co-development opportunities might benefit the missions of other DOE offices and programs or other federal agencies. For example, some development opportunities may promote energy efficiency, renewable energy development, energy and environmental justice, or missions other than the IWM Program. Consistent with a whole-of-government approach, collaboration with these other agencies or departments could strengthen the value of the co-development opportunities concept by broadening the array of available opportunities. The type of assistance needed by communities to pursue or implement co-development will vary by both the opportunity type and community. Potentially, DOE-NE would commit different levels of assistance depending on the degree to which the opportunity directly supports its missions. In addition to or instead of direct assistance, DOE-NE could play a pivotal role in establishing collaborations with other organizations to help pursue an opportunity. Criteria defining the types of opportunities that DOE-NE would support and the amount or type of support it would provide should be communicated to stakeholders when the co-development opportunities concept is announced.

2.3 Addressing Equity and Environmental Justice Issues

The co-development opportunities concept can directly support DOE-NE's commitment to equity and environmental justice. Depending on the community and the needs and interests of specific stakeholders within that community, co-development may be a way to avoid, minimize, or offset disproportionately adverse impacts on underserved and overburdened populations resulting from CISF construction and operations. In this context, co-development would become an impact mitigation measure. Co-development could also assist a community or specific underserved and overburdened populations by addressing inequities unrelated to hosting a CISF that have been incurred as a result of other current or past actions. In this context, co-development would be construed more as an incentive than as mitigation. In either case, co-development could be instrumental in centering equity and environmental justice in the consent-based siting process. Future assessment is needed to understand how CISF siting and specific co-

development opportunities could contribute to DOE's Justice 40 implementation goals^c and DOE's Equity Action Plan.^d

2.4 Building Support Beyond a Host Community

To serve as an incentive for hosting a CISF, a co-development opportunity must generate direct benefits to the potential host community. However, consent to host a CISF must be given by all affected parties, including those outside of the local community. A lack of consent from all affected parties could become a barrier to successfully siting a CISF. Benefits extending beyond the local host community to the county- or state-level could reduce broader opposition to locating a CISF at a specific site. The co-development could be physically located in or near the host community, but it could conceivably be located elsewhere provided that it still directly benefited the host community. Offering incentives to these other stakeholders may be an effective strategy for ensuring a successful outcome.

2.5 Facilitating Community Discussion About Co-Development Opportunities

A fundamental element of the consent-based siting process is the distribution of resources to communities and their stakeholders to support informed participation in the process. These resources will take multiple forms, including dissemination of understandable, relatable information about the potential effects of hosting a CISF. Resources would also include the development of tools to help stakeholders contextualize conceptual information and evaluate the tradeoffs between potential beneficial and adverse effects. Similar information and analysis tools will be needed to support informed discussions about potential co-development opportunities.

Specific aspects that communities will need to consider include:

- identifying and assessing community interests and priorities that might shape the type of co-development opportunity that would be of value;
- evaluating opportunities in the context of existing comprehensive plans to help define the desired objectives, scale, location, and other key attributes;^e
- evaluating the potential benefits and adverse effects of potential co-development opportunities in the context of the CISF hosting opportunity and the needs of specific stakeholders within the community; and
- developing an agreed-upon set of criteria for making community-wide decisions and achieving consent about co-development.

In addition to relevant information and analysis tools, communities may need direct assistance to facilitate discussion and evaluation. This assistance could include supporting public meetings and workshops or providing funds to hire planning staff or consultants. This assistance should also be well-coordinated with

^c <https://www.energy.gov/diversity/justice40-initiative>

^d https://www.energy.gov/sites/default/files/2022-04/DOE%20Equity%20Action%20Plan_Letterhead.pdf

^e Comprehensive plans can take many forms and individually or collectively establish a vision for the future of a community and define actions and timelines for achieving that vision. Typically, such plans are developed through community-wide discussion and, therefore, may establish priorities or provide guidelines for evaluating both the CISF hosting opportunity and co-development opportunities.

other assistance related to consent-based siting of a CISF to maximize stakeholders' ability to understand tradeoffs and articulate their preferences.

3. POTENTIAL CO-DEVELOPMENT OPPORTUNITIES

As discussed in Section 2, the type of co-development that would provide an incentive will vary by community. To help frame discussions around co-development, Table 1 presents an exploratory but not exhaustive list of potential opportunities broken into high-level categories; note that some of the categories may overlap.

Potential benefits and adverse effects related to co-development will vary depending on a project's design and location. These effects can be categorized as follows:

- Utilities and resource consumption (e.g., water and energy use and/or generation);
- Environmental effects (e.g., ecology, air, and water); Recreation and tourism impacts (e.g., stigma, land use)
- Socioeconomic effects (e.g., jobs and revenue);
- Community wellbeing (e.g., housing, public and social services, education, traffic, cultural changes, and other aspects of quality of life);
- Equity and environmental justice impacts (including past, present, and future);
- Infrastructure effects (e.g., local transportation, utilities, and communication services); and
- Government benefits (e.g., tax revenue).

As noted in Section 2.5, in order to consider co-development opportunities, stakeholders will need access to understandable, relatable information about the potential effects of co-development projects. In addition, they will benefit from access to tools to help them contextualize conceptual information and evaluate the tradeoffs between potential beneficial and adverse effects of various co-development opportunities.

While it is most effective for communities and stakeholders to identify their priorities regarding co-development, providing examples could help them see opportunities they might not otherwise consider. This is supported by Nussbaum (2007) who points out that communities considering compensation and incentives are influenced by adaptive preferences, meaning that their imagination for potential opportunities are often constrained by what is familiar to them.

During the early phases of consent-based siting, information about CISF siting considerations cannot be site- or project-specific and will necessarily be based upon generic facilities and hypothetical or genericized locations. Similarly, information about siting co-development opportunities cannot be site- or project-specific. However, relevant information can be derived from generic analyses and relevant case-studies.

Appendix A provides summaries of available information about siting considerations associated with examples of co-development opportunities. The opportunities selected as examples are behind-the-meter solar for public buildings, greenspace development, a science and technology park, and small modular reactor manufacturing. These co-development opportunities, representing a diverse set of opportunities, were chosen to provide a proof-of-concept demonstration of the type of information that can be derived from existing sources. Such information is used to inform stakeholders about the potential siting considerations, such as benefits, adverse effects, barriers, and constraints associated with specific opportunities. These examples are meant to be a starting point for conversations and communications with stakeholders about co-development opportunities and should not be limited to what is presented here.

Table 1. Potential Co-Development Opportunity Projects.

Category	Example Project
Light manufacturing	Nuclear industry • Small modular reactor (SMR) component manufacturing • SNF storage and transportation canisters and casks Non-nuclear industries • Renewable energy components (e.g., solar modules, inverters, wind turbine blades) • Electronics, appliances, furniture, and other durable consumer products • Commercial food production (e.g., dairies, bakeries, canneries)
R&D	Office and laboratory facilities supporting research, development, and/or demonstration of new products, technologies, or services in either the nuclear or non-nuclear fields, or both
Infrastructure investment	Construction, expansion, or modernization of infrastructure systems such as: • Energy distribution • Water treatment and/or distribution • Irrigation • Communications • Transportation • Waste management
Clean energy generation	Investments in new clean energy generation facilities that support goals to reduce greenhouse gas emissions, build energy system resiliency, and promote energy independence, such as: • Distributed or centralized renewable energy generation and battery storage • SMR operation
Education and training	Investments in new or existing educational and training facilities, such as: • Public or private colleges and trade schools supporting general education and/or workforce development • Government-funded training facilities • Technology upgrades for local primary and secondary schools
Climate resiliency and environment	In addition to investments in clean energy generation, investments in other measures, such as: • Energy efficiency • Flood hazard mitigation • Landscaping improvements (e.g., permeable landscapes, tree canopy, pollinator habitat) • Environmental remediation and/or restoration
Community well-being	Investments in facilities, services, and infrastructure that enhance the health, stability, and general well-being of community members, such as: • Public health services (e.g., clinics, hospitals, emergency medical services) • Affordable housing investment • Community centers, parks, and recreation facilities • Cultural heritage preservation
Other economic opportunities	Investments in facilities, services, and infrastructure to promote other forms of economic growth, such as • Tourism (e.g., museums, ecotours, recreation facilities) • Cultural facilities (e.g., museums, performing arts centers)

Four specific types of co-development, representing a diverse set of opportunities, were chosen to provide a proof-of-concept demonstration of the type of information that can be derived from existing sources. Further consideration is needed to determine the level of detail that stakeholders would need to evaluate whether co-development would be an effective incentive for hosting a CISF. Further consideration would also be needed to determine the most effective methods for communicating with stakeholders. The availability of applicable case study data varies widely depending on the co-development opportunity under consideration. For example, because solar installations have gained popularity there is a larger pool of knowledge to draw from than an opportunity that is considering small modular reactor manufacturing. Prior to presenting the co-development opportunities concept, more analysis should be completed to

ensure complete and consistent information is available to communities and stakeholders about the types of potential opportunities that may become available. At a minimum, to the extent relevant or applicable, information provided to stakeholders about possible co-development opportunities should include discussion of potential benefits, adverse effects, barriers, and constraints associated with the following:

- Utilities and resource use,
- Environment,
- Recreation and tourism,
- Socioeconomics,
- Community well-being,
- Equity and environmental justice,
- Infrastructure, and
- Government benefits.

4. RECOMMENDATIONS FOR A CO-DEVELOPMENT OPPORTUNITIES STRATEGY

A comprehensive strategy for implementing and communicating the co-development opportunities concept should be developed. The following recommendations are offered for consideration in such a strategy. These recommendations are shaped by stakeholder input provided in response to the 2021 RFI (DOE 2022), other considerations discussed in Section 2, and the proof-of-concept evaluations presented in Appendix A.

- Co-development opportunities should be presented to stakeholders early in the consent-based siting process to maximize their value in generating interest in hosting a CISF. Similarly, they should be presented to Tribes early in formal government-to-government consultation process.
- Communications about co-development should impart a clear message that these opportunities represent incentives and/or compensation for hosting a CISF. Messages must counter perceptions that these opportunities are bribes intended to induce a community into hosting a CISF when it is not in its best interest. A dedicated literature review in this area could be helpful.
- Communications should also impart a clear message about the potential opportunities for co-development to help address equity and environmental justice issues.
- Communities should be given latitude to define the type(s) of co-development that would align with their interests and priorities and, thus, serve as an effective incentive for hosting a CISF.
- If DOE-NE establishes limits on the type of co-development it will support, it should seek to minimize the effect of such limits on community choice and it should communicate such limits at the outset when presenting the opportunity to stakeholders.
- DOE-NE should evaluate opportunities to collaborate with other organizations to embrace a whole-of-government approach that might maximize the feasibility and impact of co-development.
- To facilitate community discussions about co-development, relevant information should be shared about siting considerations, including potential benefits, adverse effects, barriers, and constraints, associated with a broad array of opportunity types. In the absence of specific projects and locations, this information should be based on available information, including case studies, other publications, and limited new research and analysis.

- Information about co-development siting considerations could be shared on a dedicated StoryMap which, consistent with other stakeholder siting tools, would provide relevant data and visualization tools to help stakeholders contextualize information and assess tradeoffs between options. Information also could potentially be shared via the proposed Land-area Identification, Tagging, and Exploration (LITE) geospatial data evaluation tool.
- If needed, DOE-NE should support community efforts to evaluate co-development opportunities. This could include supporting public meetings and workshops or providing funding for hiring planning staff or consultants. This support could be provided directly to a community, or it could be provided through the services of future collaboration centers.
- Potentially, a future funding opportunity could solicit proposals from communities or collaboration centers seeking assistance in pursuing and shaping visions around co-development as an incentive for hosting a CISF.

Next steps for investigating co-development opportunities could include the following:

- Researching literature and case study experiences related to government-supported incentive programs;
- Defining DOE priorities to establish the (1) scope of co-development opportunities that potentially would be supported and (2) the form and extent of support that would be offered;
- Developing an implementation plan that addresses messaging, timing, mechanism(s) for supporting co-development, and potential collaborations with other organizations; and
- Conducting new analysis of the impacts of different opportunities, developing partnerships and a comprehensive strategy with others working on consent-based siting, and exploring options for presenting the co-development information in a StoryMap.

5. REFERENCES

- . 2020. “Solar Garden Installation Completed - Clean Affordable Energy Production to Begin in 2021.” Boulder Housing Partners. December 8, 2020. <https://boulderhousing.org/news/solar-garden-installation-completed-clean-affordable-energy-production-begin-2021>.
- ABC7. 2022. “Solar Power Finds Floating Home in Healdsburg along Russian River.” ABC7 San Francisco. May 18, 2022. <https://abc7news.com/floating-solar-farm-healdsburg-russian-river-power-north-bay-production/11846953/>.
- Aman, M. M., K. H. Solangi, M. S. Hossain, A. Badarudin, G. B. Jasmon, H. Mokhlis, A. H. A. Bakar, and S. N Kazi. 2015. “A Review of Safety, Health and Environmental (SHE) Issues of Solar Energy System.” *Renewable and Sustainable Energy Reviews* 41 (January): 1190–1204. <https://doi.org/10.1016/j.rser.2014.08.086>.
- Armstrong, Alona, Trevor Page, Stephen J. Thackeray, Rebecca R. Hernandez, and Ian D. Jones. 2020. “Integrating Environmental Understanding into Freshwater Floatovoltaic Deployment Using an Effects Hierarchy and Decision Trees.” *Environmental Research Letters* 15 (11): 114055. <https://doi.org/10.1088/1748-9326/abbf7b>.
- Bazilian, Morgan, Ijeoma Onyeji, Michael Liebreich, Ian MacGill, Jennifer Chase, Jigar Shah, Dolf Gielen, Doug Arent, Doug Landfear, and Shi Zhengrong. 2013. “Re-Considering the Economics of Photovoltaic Power.” *Renewable Energy* 53 (Supplement C): 329–38. <https://doi.org/10.1016/j.renene.2012.11.029>.
- BHP. 2018. “Boulder Housing Partners Opens Palo Park - New Affordable Community Appealing to Area Workers.” Boulder Housing Partners. 2018. <https://boulderhousing.org/news/palo-park-opening>.
- “Boulder Housing Partners.” n.d. Clean Energy Group (blog). Accessed August 7, 2022. <https://www.cleangroup.org/ceg-projects/resilient-power-project/featured-installations/boulder-housing-partners/>.
- “Boulder Housing Partners: Solar at BHP.” 2022. February 9. https://boulderhousing.org/sites/default/files/page_attachments/2022_bhp_board_presentation_-_solar.pdf.
- “Bronzeville Context.” n.d. Chicago.Gov. Accessed August 7, 2022. https://www.chicago.gov/content/dam/city/depts/dcd/cnn/Bronzeville_Context_1.pdf.
- “Bronzeville: The ‘Black Metropolis’ of Chicago.” 2020. Main Street America. February 26, 2020. <https://www.mainstreet.org/blogs/national-main-street-center/2020/02/26/bronzeville-the-black-metropolis>.
- Bureau of Economic Analysis. 2017. “Outdoor Recreation Satellite Account, U.S. and Prototype for States.” Washington, D.C.: Bureau of Economic Analysis, U.S. Department of Commerce. <https://www.bea.gov/data/special-topics/outdoor-recreation>.
- Carlton, J. Stuart, Andrew Ropicki, and B. Balboa. 2016. “The Half Moon Reef Restoration: A Socioeconomic Evaluation.” TAMU-SG-16-211. College Station, TX: Texas Sea Grant College Program.
- Cavaye, Jim. 2001. “Rural Community Development: New Challenges and Enduring Dilemmas.” *Journal of Regional Analysis & Policy* 31 (1): 109–24.
- Christakopoulou, Sophia, Jon Dawson, and Aikaterini Gari. 2001. “The Community Well-Being Questionnaire: Theoretical Context and Initial Assessment of Its Reliability and Validity.” *Social Indicators Research* 56 (3): 319–49. <https://doi.org/10.1023/A:1012478207457>.

City of Healdsburg. 2021. "Fact Sheet: City of Healdsburg's Floating Photovoltaic Solar Array." https://www.ci.healdsburg.ca.us/DocumentCenter/View/12971/Solar-Project-OnePager_Feb1201.

"City of Plano Solar Farm 'Energized' and Fully Operational." 2021. Cision PR Newswire. February 17, 2021. <https://www.prnewswire.com/news-releases/city-of-plano-solar-farm-energized-and-fully-operational-301230326.html>.

Cohn, Lisa. 2019. "Solar Housing Linked to Bronzeville Microgrid Provides Social Justice, Technology Research." Microgrid Knowledge. June 14, 2019. <https://microgridknowledge.com/bronzeville-microgrid-social-justice-solar/>.

Collins, Mary Kayla, and Annick Anctil. 2017. "Implications for Current Regulatory Waste Toxicity Characterisation Methods from Analysing Metal and Metalloid Leaching from Photovoltaic Modules." International Journal of Sustainable Energy 36 (6): 531–44. <https://doi.org/10.1080/14786451.2015.1053392>.

ComEd. n.d. "Bronzeville Community Microgrid." Accessed August 15, 2022. <https://www.meeaconference.org/sites/meeaconference.org/files/D2%20-%20DeSalvo-Russ.pdf>.

"Core Components." 2019. Resilience Hubs (blog). July 29, 2019. <http://resilience-hub.org/core-components/>.

Cumo, F., B. De Lieto Vollaro, E. Pennacchia, M. Sforzini and V. Sforzini (2016). "Technology park in connection with national filing of radioactive waste." International Journal of Sustainable Development and Planning 11(5): 751-758.

D'Souza, Nidgel. n.d. "How Rising Solar Artist Shala Is Quietly Redefining Art and Influence." Kulture Hub. Accessed August 7, 2022. <https://kulturehub.com/shala-solar-art/>.

EERE. n.d. "PROJECT PROFILE: Commonwealth Edison Company (SHINES)." Energy.Gov. Accessed August 15, 2022. <https://www.energy.gov/eere/solar/project-profile-commonwealth-edison-company-shines>.

Energetics Incorporated. (2012). U.S. Manufacturing Energy Use and Greenhouse Gas Emissions Analysis.

Federal Register, Vol. 86, Number 228, pp 68244-68246; <https://www.govinfo.gov/content/pkg/FR-2021-12-01/pdf/2021-25724.pdf>

Fthenakis, Vasilis, and Hyung Chul Kim. 2010. "Life-Cycle Uses of Water in U.S. Electricity Generation." Renewable and Sustainable Energy Reviews 14 (7): 2039–48. <https://doi.org/10.1016/j.rser.2010.03.008>.

Gao, Xue, and Shan Zhou. 2022. "Solar Adoption Inequality in the U.S.: Trend, Magnitude, and Solar Justice Policies." Energy Policy 169 (October): 113163. <https://doi.org/10.1016/j.enpol.2022.113163>.

Garfield Legacy Project. 2012. "Garfield County Greenprint for Conservation and Economic Opportunity." Summary Report. Garfield County, CO: Garfield Legacy Project, The Trust for Public Land, Sonoran Institute.

Guidi, G., F. Gugliermetti, D. Astiaso Garcia and A. Violante (2009). "Influence of environmental, economic and social factors on a site selection index methodology for a technological centre for radioactive waste management."

Habib, Cyrus. 2017. Certification of Enrollment: Engrossed Substitute Senate Bill 5939: Renewable Energy- Tax Incentives- Fees. <https://lawfilesexxt.leg.wa.gov/biennium/2017-18/Pdf/Bills/Session%20Laws/Senate/5939-S.SL.pdf?q=20210923061331>.

Hannis, Mike, and Kate Rawls. "Compensation or Bribery? Ethical Issues in Relation to Radwaste Host Communities." In *Social and Ethical Aspects of Radiation Risk Management*, edited by D Oughton and S.O. Hansson. Elsevier Science.

Headwaters Economics. 2019. "Recreation Counties Attracting New Residents and Higher Incomes." <https://headwaterseconomics.org/wp-content/uploads/recreation-counties-attract-report.pdf>.

Henderson, Audrey. 2020. "Chicago Microgrid Project Attempts to Balance Corporate, Community Needs." *Energy News Network*. February 17, 2020. <https://energynews.us/2021/02/17/chicago-microgrid-project-attempts-to-balance-corporate-community-needs/>.

Hernandez, R. R., S. B. Easter, M. L. Murphy-Mariscal, F. T. Maestre, M. Tavassoli, E. B. Allen, C. W. Barrows, et al. 2014. "Environmental Impacts of Utility-Scale Solar Energy." *Renewable and Sustainable Energy Reviews* 29 (January): 766–79. <https://doi.org/10.1016/j.rser.2013.08.041>.

Hill, David. n.d. "The Solar Strand." University of Buffalo. Accessed August 13, 2022. https://www.buffalo.edu/home/feature_story/solar-strand.html.

Holland, W. Hunter, Robert B. Powell, Jennifer M. Thomsen, and Christopher A. Monz. 2018. "A Systematic Review of the Psychological, Social, and Educational Outcomes Associated With Participation in Wildland Recreational Activities." *Journal of Outdoor Recreation, Education, and Leadership* 10 (3). <https://doi.org/10.18666/JOREL-2018-V10-I3-8382>.

HOMER Software. n.d. "HOMER Pro." Accessed August 28, 2022. <https://www.homerenergy.com/products/pro/index.html>

Ibabao, Rhodella A, Maria Elisa D Baliao, and Joy C Lizada. 2013. "A Review of Free Prior Informed Consent Implementation: The Case of a Large Dam Project in Iloilo, Philippines." *Philippine Journal of Social Sciences and Humanities* 18 (2): 49–63.

Jack's Solar Garden, LLC. n.d. "Solar Energy Colorado." Jack's Solar Garden. Accessed August 13, 2022. <https://www.jackssolargarden.com>.

Jager, Henriette I., Rebecca A. Efroymson, and Ryan A. McManamay. 2021. "Renewable Energy and Biological Conservation in a Changing World." *Biological Conservation* 263 (November): 109354. <https://doi.org/10.1016/j.biocon.2021.109354>.

Journal Staff. 2020. "New Solar Field In Long Grove Includes Student Artwork." *Journal & Topics Media Group*, November 28, 2020. <https://www.journal-topics.com/articles/new-solar-field-in-long-grove-includes-student-artwork/>.

"Kari, Mika, Matti Kojo, Markku Lehtonen. 2021. "Role of the host communities in final disposal of spent nuclear fuel in Finland and Sweden." *Progress in Nuclear Energy* 133 (2021) 103632. <https://www.sciencedirect.com/science/article/pii/S0149197021000044?via%3Dihub>.

KCSD District 96. 2021. "KCSD Kildeer Countryside School District 96 District Review: A Solar Celebration at District 96." KCSD District 96. <https://campussuite-storage.s3.amazonaws.com/prod/750226/93147715-c5f6-11e6-b7b7-22000bd8490f/2324768/23a19eea-26ac-11ec-861b-0e9f2a8d3893/file/KCSD96%20District%20Update%202021%20FINAL.pdf>.

Kellert, Stephen R., D. J. Case, Dan Escher, D. Witter, J. Mikels-Carrasco, and P. T. Seng. 2017. "The Nature of Americans: Disconnection and Recommendations for Reconnection." Mishawaka, IN: DJ Case and Associates. <https://natureofamericans.org/>.

Kline, John. 2019. "Two Goshen Schools May Use Solar Power in the Future." *Goshen News*. August 13, 2019. https://www.goshennews.com/news/local_news/two-goshen-schools-may-use-solar-power-in-the-future/article_a033b14e-fafe-5a02-b544-33f3d81d7e51.html.

Kolberg, J. (2020). "Economic Impact Assessment: Sandia Science & Technology Park."

Kusharsanto, Z. S. and L. Pradita (2016). "The Important Role of Science and Technology Park towards Indonesia as a Highly Competitive and Innovative Nation." *Procedia - Social and Behavioral Sciences* 227: 545-552.

Kyle, Gerard, Alan Graefe, Robert Manning, and James Bacon. 2003. "An Examination of the Relationship between Leisure Activity Involvement and Place Attachment among Hikers Along the Appalachian Trail." *Journal of Leisure Research* 35 (3): 249–73.
<https://doi.org/10.1080/00222216.2003.11949993>.

Larson, Eric C., and Richard S. Krannich. 2016. "'A Great Idea, Just Not Near Me!' Understanding Public Attitudes About Renewable Energy Facilities." *Society & Natural Resources* 29 (12): 1436–51.
<https://doi.org/10.1080/08941920.2016.1150536>.

Lee, KangJae Jerry, Jonathan Casper, and Myron Floyd. 2020. "Racial and Ethnic Diversity and Inclusion Efforts of Public Park and Recreation Agencies." *Journal of Park & Recreation Administration* 38 (1): 88–105. <https://doi.org/10.18666/JPra-2019-9785>.

"Local Government Renewables Action Tracker." n.d. American Cities Climate Challenge. Accessed August 12, 2022. <https://cityrenewables.org/local-government-renewables-action-tracker/>.

Longo Better, Rossana. 2022. "A Solar Garden Offers a Solution to Lower Energy Costs for Mobile Home Residents in Boulder." KSUT Public Radio. February 2, 2022. <https://www.ksut.org/environment-climate/2022-02-01/a-solar-garden-offers-a-solution-to-lower-energy-costs-for-mobile-home-residents-in-boulder>.

Louv, Richard. 2008. *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Algonquin Books.

Lu, Xiaonan, Shay Bahramirad, Jianhui Wang, and Chen Chen. 2015. "Bronzeville Community Microgrids: A Reliable, Resilient and Sustainable Solution for Integrated Energy Management with Distribution Systems." *The Electricity Journal* 28 (10): 29–42. <https://doi.org/10.1016/j.tej.2015.11.009>.

Mavilia, R., M. Ferrara and F. Lamperti (2014). *The Impact of Technopoles and Science Parks on the Regional and Local Innovation Systems*: 51-76.

Miller, Clark A., Jennifer Richter, and Jason O'Leary. 2015. "Socio-Energy Systems Design: A Policy Framework for Energy Transitions." *Energy Research & Social Science* 6 (March): 29–40.
<https://doi.org/10.1016/j.erss.2014.11.004>.

Moore-O'Leary, Kara A., Rebecca R. Hernandez, Dave S. Johnston, Scott R. Abella, Karen E. Tanner, Amanda C. Swanson, Jason Kreitler, and Jeffrey E. Lovich. 2017. "Sustainability of Utility-Scale Solar Energy – Critical Ecological Concepts." *Frontiers in Ecology and the Environment* 15 (7): 385–94.
<https://doi.org/10.1002/fee.1517>.

Mueller, J. Tom, and Ann R. Tickamyer. 2020. "A More Complete Picture: Rural Residents' Relative Support for Seven Forms of Natural Resource-Related Economic Development." *Rural Sociology* 85 (2): 376–407. <https://doi.org/10.1111/ruso.12293>.

Mytton, D. (2021). "Data centre water consumption." *npj Clean Water* 4(1).

National Renewable Energy Laboratory (NREL). 2013. "Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics." NREL. 2013. <https://www.nrel.gov/docs/fy13osti/56487.pdf>.

National Renewable Energy Laboratory (NREL). n.d. "PVWatts Calculator." Accessed August 28, 2022. <https://pvwatts.nrel.gov/>

National Renewable Energy Laboratory (NREL). n.d. "REopt: Renewable Energy Integration & Optimization." Accessed August 28, 2022. <https://reopt.nrel.gov/>

National Renewable Energy Laboratory (NREL). n.d. “System Advisor Model (SAM).” Accessed August 28, 2022. <https://sam.nrel.gov/>

“New Mural Tells The Story of Bronzeville.” 2020. Exelon. September 28, 2020. <https://www.exeloncorp.com:443/grid/new-mural-tells-the-story-of-bronzeville>.

Nussbaum, Martha C. 2007. *Frontiers of Justice: Disability, Nationality, Species Membership* (Tanner Lectures of Human Values). Cambridge, MA: Belknap Press of Harvard University Press.

O’Neil, Rebecca S., D. C. Preziuso, Katie K. Arkema, Yekang Ko, Nicholas Pevzner, Kirk Dimond, Simon Gore, Katherine Morrice, Chris D. Henderson, and Devyn Powell. 2022. “Renewable Energy Landscapes: Designing Place-Based Infrastructure for Scale.” PNNL-32680. Richland, WA: Pacific Northwest National Laboratory.

Outdoor Foundation. 2019. “State Offices of Outdoor Recreation.” Accessed August 16, 2022. <https://outdoorindustry.org/advocacy/state-offices-outdoor-recreation/>

Outdoor Foundation. 2020. “2019 Outdoor Participation Report.” Boulder, CO: Outdoor Foundation.

Pedlar, A. M. 1996. “Community Development: What Does It Mean for Recreation and Leisure?” *Journal of Applied Recreation Research* 21 (1): 5–23.

Powell, Robert, Jennifer Thomsen, and D. Allen. 2013. “Park Health Resources: Benefits, Values, and Implications.” *Park Science* 30 (2): 30–36.

Reames, Tony G. 2020. “Distributional Disparities in Residential Rooftop Solar Potential and Penetration in Four Cities in the United States.” *Energy Research & Social Science* 69 (November): 101612. <https://doi.org/10.1016/j.erss.2020.101612>.

Rice, William L, Timothy J Mateer, Nathan Reigner, Peter Newman, Ben Lawhon, and B Derrick Taff. 2020. “Changes in Recreational Behaviors of Outdoor Enthusiasts during the COVID-19 Pandemic: Analysis across Urban and Rural Communities.” *Journal of Urban Ecology* 6 (1): juaa020. <https://doi.org/10.1093/jue/juaa020>.

Sachs, Noah M. 1996. “The Mescalero Apache Indians and Monitored Retrievable Storage of Spent Nuclear Fuel: A Study in Environmental Ethics.” *Natural Resources Journal* 36: 881–912.

Schlegelmilch, Jeffrey, Jackie Ratner, Daniel Kushner, and Susanna Aguilar. 2021. “An Exercise in Resilience: Testing the Bronzeville Community Microgrid.” August 21, 2021. <https://hazards.colorado.edu/news/research-counts/an-exercise-in-resilience-testing-the-bronzeville-community-microgrid>.

Semmler, Ed. 2021. “Sun-Powered Savings: John Glenn, Goshen and Other Schools Look to Cut Costs with Solar.” *South Bend Tribune*, January 23, 2021. <https://www.southbendtribune.com/story/news/education/2021/01/23/sun-powered-savings-john-glenn-goshen-and-other-schools-look-to-cut-costs-with-sola/43904609/>.

Shields, Todd. 2019. “Kildeer-Countryside School District 96 Officials Attend Village Board Meeting in Push for Solar Field.” *Chicago Tribune*, January 28, 2019. <https://www.chicagotribune.com/suburbs/buffalo-grove/ct-bgc-school-solar-panels-tl-0131-story.html>.

Sinha, Parikhit, Garvin Heath, Andreas Wade, and Keiichi Komoto. 2020. “Human Health Risk Assessment Methods for PV, Part 3: Module Disposal Risks.” T12-16:2020. International Energy Agency Photovoltaic Power Systems Programme Task 12. <https://iea-pvps.org/key-topics/human-health-risk-assessment-methods-for-pv-part-3-module-disposal-risks/>.

Smith, K.P., K. Banerjee, D.M. Anderson, et al. 2021. DRAFT Associated Siting Support Tools Development: FACET and OR-SAGE Feasibility Study and Proof-of-Concept Report. Prepared for the U.S. Department of Energy, Office of Integrated Waste Management by Pacific Northwest National

Laboratory, Oak Ridge National Laboratory, and Argonne National Laboratory. PNNL-32439. Dec. 17, 2021.

Solar Energy Industries Association, The Solar Foundation, Interstate Renewable Energy Council (IREC), and B.W. Research Partnership. 2021. “11th Annual National Solar Jobs Census 2020.” Interstate Renewable Energy Council (IREC). <https://irecusa.org/wp-content/uploads/2021/07/National-Solar-Jobs-Census-2020-FINAL.pdf>.

“Solar Field Dispute Pits School District vs. Long Grove Horse Farm Owners, Residents.” 2019. Daily Herald. 2019. <https://www.dailyherald.com/news/20190121/solar-field-dispute-pits-school-district-vs-long-grove-horse-farm-owners-residents>.

“Solar Panels.” n.d. Washington State Department of Ecology. Accessed December 3, 2021. <https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Our-recycling-programs/Solar-panels>.

“Solar.” n.d. Meridian Township, MI. Accessed July 29, 2022. <https://www.meridian.mi.us/community/green-meridian/solar>.

Spiess, Thierry, and Christopher de Sousa. 2016. “Barriers to Renewable Energy Development on Brownfields.” *Journal of Environmental Policy & Planning* 18 (4): 507–34. <https://doi.org/10.1080/1523908X.2016.1146986>.

St. John, Jeff. 2022. “The Country’s First Neighborhood Microgrid Is Coming Online in Chicago.” Canary Media. February 9, 2022. <https://www.canarymedia.com/articles/grid-edge/the-countrys-first-neighborhood-microgrid-is-coming-online-in-chicago>.

State Government Leadership Foundation. 2020. “Net Metering in the States: A 2020 Update.” State Government Leadership Foundation. December 17, 2020. <https://www.sglf.org/blog/net-metering-in-the-states-a-2020-update>.

Steinbrecher, Stephanie. 2018. “100 U.S. Cities Are Committed to 100 Percent Clean, Renewable Energy.” Sierra Club. December 5, 2018. <https://www.sierraclub.org/press-releases/2019/03/100-us-cities-are-committed-100-percent-clean-renewable-energy>.

Stewards of Affordable Housing for the Future. 2022. “Expanding Access to Community Solar for Affordable Housing Residents: Tip Sheet.” Stewards of Affordable Housing for the Future. https://sahfnet.org/sites/default/files/uploads/resources/ncsp_resident_tip_sheet_-_winter_2022.pdf.

Summers, J. K., L. M. Smith, J. L. Case, and R. A. Linthurst. 2012. “A Review of the Elements of Human Well-Being with an Emphasis on the Contribution of Ecosystem Services.” *AMBIO* 41 (4): 327–40. <https://doi.org/10.1007/s13280-012-0256-7>.

Sunter, Deborah A., Sergio Castellanos, and Daniel M. Kammen. 2019. “Disparities in Rooftop Photovoltaics Deployment in the United States by Race and Ethnicity.” *Nature Sustainability* 2 (1): 71. <https://doi.org/10.1038/s41893-018-0204-z>.

“The Plano Project.” n.d. CED Greentech. Accessed August 12, 2022. <https://www.cedgreentech.com/customer-project/plano-project>.

Torres-Pruñonosa, J., J. M. Raya and R. Dopeso-Fernández (2020). “The Economic and Social Value of Science and Technology Parks. The Case of Tecnocampus.” (1664-1078 (Print)).

U.S. Department of Energy (DOE). 2022. Responses to the Request for Information on Using a Consent-Based Siting Process to Identify Federal Interim Storage Facilities. U.S. Department of Energy, Office of Nuclear Energy. March 2022. <https://www.energy.gov/sites/default/files/2022-06/Responses%20to%20RFI%20on%20Consent-Based%20Siting%20and%20Interim%20Storage%20Updated.pdf>

U.S. Department of Energy, National Association of State Energy Officials (NASEO), Energy Futures Initiative, and BW Research Partnership, Inc. 2021. “United States Energy & Employment Report 2021.” U.S. Department of Energy. <https://www.energy.gov/us-energy-employment-jobs-report-useer>.

U.S. Energy Information Administration. (2018). "Use of Energy Explained: Energy use in commercial buildings." from <https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings-in-depth.php>.

Ulrich-Schad, Jessica D., Paul M. Jakus, Malieka Bordigioni, and Don E. Albrecht. 2022. “Preferences for Economic and Environmental Goals in Rural Community Development in the Western United States*.” *Rural Sociology* 87 (2): 605–41. <https://doi.org/10.1111/ruso.12429>.

University at Buffalo Libraries. n.d. “Solar Strand.” University at Buffalo. Accessed August 13, 2022. <https://library.buffalo.edu/archives/campuses/detail.html?ID=81>.

“VLV Development Completes 1.1MW Solar Facility Serving Bronzeville Public Housing.” 2020. RE Journals. October 22, 2020. <https://rejourneys.com/vlv-development-completes-1-1mw-solar-facility-serving-bronzeville-public-housing/>.

Watson, Keri B., Taylor Ricketts, Gillian Galford, Stephen Polasky, and Jarlath O’Niel-Dunne. 2016. “Quantifying Flood Mitigation Services: The Economic Value of Otter Creek Wetlands and Floodplains to Middlebury, VT.” *Ecological Economics* 130 (October): 16–24. <https://doi.org/10.1016/j.ecolecon.2016.05.015>.

“Webinar Series: Clean Growth Incubator.” n.d. Center for Strategic Policy Innovation. Accessed August 15, 2022. <https://www.centerforstrategicpolicy.org/webinar-series>.

Weckend, Stephanie, Andreas Wade, and Garvin Heath. 2016. “End of Life Management: Solar Photovoltaic Panels.” NREL/TP-6A20-73852, 1561525. National Renewable Energy Laboratory. <https://doi.org/10.2172/1561525>.

Wede, Bob. n.d. “Goshen Schools Energy Savings Project.” Performance Services. Accessed August 7, 2022. <http://www.performanceservices.com/project/goshen-community-schools-phase-i-ii-and-iii>.

White House. 2021. “Justice40 Initiative.” The White House. 2021. <https://www.whitehouse.gov/environmentaljustice/justice40/>.

Wilson, Scott. 2020. “Amid Shut-off Woes, a Beacon of Energy.” *Washington Post*, January 1, 2020. <https://www.washingtonpost.com/climate-solutions/2020/01/01/amid-shut-off-woes-beacon-energy/>.

Womble, Joseph. 2022. “Innovative Partnerships Bring Community Solar to Low-Income Households in the U.S.” World Resources Institute. July 25, 2022. <https://www.wri.org/insights/us-community-solar-partnerships>.

XENDEE. n.d. “Microgrid Decision Support Platform.” Accessed August 28, 2022. <https://xendee.com/>

Zhuravel, Alina. 2018. “Meridian Township Invests in Renewable Energy by Installing a Solar Panel Array.” *Spartan Newsroom*. December 17, 2018. <https://news.jrn.msu.edu/2018/12/meridian-township-invests-in-renewable-energy-by-installing-a-solar-panel-array/>.

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Appendix A

Co-Development Opportunities Case Studies

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A-1. Behind-the-Meter Solar for Public Buildings

A-1.1 Description of the Development Opportunity

Behind-the-meter solar development refers to a rooftop or ground-mount solar system that meets a portion of the energy demand for an individual building (Table A-1) or end use (e.g., agriculture, manufacturing, and electric vehicle charging). The solar energy is generated and primarily consumed on-site, depending on the daytime load pattern. Behind-the-meter refers to the customer side of the electricity meter rather than the utility side. Residential solar systems can be considered behind-the-meter, but this co-development example focuses on solar systems serving a public need, to maintain focus on benefits to the local community rather than individuals. Behind-the-meter solar systems may include battery storage. These installations offer multiple benefits, including energy cost savings for public buildings and visibility of clean energy within a community. Many U.S. towns and cities are developing 100% renewable energy targets for municipal operations (Steinbrecher 2018), and behind-the-meter solar power can help meet these targets.

Planning for the development of behind-the-meter solar installations requires several types of analysis. Many municipalities or counties do not have the in-house technical expertise to independently conduct these assessments. Therefore, they incur contracting costs. In general, communities would benefit from technical support in conducting these analyses. An example of a program aiming to meet this need is a nonprofit organization called the Clean Growth Incubator, which is working with the National Renewable Energy Laboratory (NREL) on training opportunities in solar modeling software for municipal employees (“Webinar Series: Clean Growth Incubator” n.d.). DOE could assist communities with technical and social analyses during the planning phases of these projects.

One type of assessment is a solar modeling process that evaluates the technoeconomic feasibility of the proposed project—e.g., the installed capacity of the solar system, the energy generated per annum, and the cost savings over the installation’s lifespan. The modeling considers the sufficiency of the space for ground-mount solar power (which is typically cheaper than rooftop installations) or the rooftop area and orientation. The model incorporates data on the local climate (e.g., solar insolation, sunrise and sunset, and cloud cover), on-site electricity demand and electricity costs, time-of-use data (hourly and seasonal), cost of financing (interest rate), operations and maintenance costs, taxes, and financial incentives.

NREL offers three free tools for solar modeling: a cursory assessment tool called PVWatts^f and more robust tools called REOpt^g and the System Advisor Model (SAM)^h. Numerous more in-depth commercial software options are available (e.g., HOMER Proⁱ, XENDEE^j). Ideally, this solar modeling assessment is conducted with a building energy efficiency audit to identify affordable energy efficiency measures to combine with renewable energy generation. For example, if a building’s windows are inefficient and the insulation is inadequate, the full potential benefit of solar generation is lost on excess heating and cooling costs.

^f <https://pvwatts.nrel.gov/>

^g <https://reopt.nrel.gov/>

^h <https://sam.nrel.gov/>

ⁱ <https://www.homerenergy.com/products/pro/index.html>

^j <https://xendee.com/>

In addition to technical analysis, social analysis and a stakeholder or community engagement process are needed. Such assessment is often overlooked due to assumptions that the local public will automatically favor solar power. While often less contentious than siting a nuclear facility, nearby residents do not always accept solar projects (Larson & Krannich 2016). The project implementer should engage the local public in siting the system and determining what benefits should be prioritized for the community. Analysis related to social acceptance and support could include public workshops, surveys, interviews, and local citizen advisory panels. While this work is less technical than solar modeling, it does require some expertise in public engagement in energy siting.

In most U.S. communities, solar installations must be grid-tied. Depending on local utility regulations, any surplus electricity that exceeds demand during the day may be fed back into the grid. The rate at which the building occupant is reimbursed for this electricity affects the financial feasibility of the installed solar system. Public utility commissions across the country are adjudicating this reimbursement rate, which ranges from the wholesale rate paid to power plant operators to the retail rate or even a subsidized rate (State Government Leadership Foundation 2020). There are often regulatory barriers to developing behind-the-meter solar power, such as utility restrictions on the size of the solar installation, which can impede the financial viability of projects.

DOE could be involved in behind-the-meter solar development as a co-development project by offering technical assistance in terms of technoeconomic and social assessment, providing grant funding especially for battery storage, and funding the deployment of new solar and battery storage technologies to improve the technology and reduce its cost.

A-1.1.1 Case Studies on Behind-the-Meter Solar Development: Overview

There are numerous examples of behind-the-meter solar systems across the country. The Local Government Renewables Action Tracker, maintained by an energy NGO called the Rocky Mountain Institute, lists 493 on-site projects or community renewable energy projects (primarily solar power) across the country, built between early 2015 and March 31, 2021 (“Local Government Renewables Action Tracker” n.d.). Each solar installation is somewhat unique because it is tailored to the needs of the local site and community. This section overviews several examples at schools, municipal buildings, public housing, and water treatment facilities.

Table A-1. Example Locations of Behind-the-Meter Solar Installations Focused on Community-Scale Benefits (Rather Than Individual or Private).

Example Locations of Behind-the-Meter Solar Projects
Community centers
Municipal office buildings (See Fig. 1)
Parks & recreation facilities
Police/fire stations
Fish hatcheries ^k
Convention centers
Libraries
Affordable housing projects
Homeless shelters
Parking structures

A behind-the-meter ground-mount solar system at a municipal building in Meridian Charter Township, Michigan (Fig. A-1) is surrounded by pollinator-friendly vegetation. This 20-kW system provides a portion of the building's electricity needs. The building (not pictured) is directly behind the installation. The modules are visible to local citizens from a busy traffic intersection. The installation counts toward a township goal of 100% renewable energy by 2035. The township also has existing or in-progress behind-the-meter solar installations at a fire station, farmers' market pavilion, police building, and service center (Zhuravel 2018; "Solar" n.d.).

Figure A-1. A behind-the-meter ground-mount solar system at a municipal building in Meridian Charter Township, Michigan. (Photo by Sharlissa Moore.).



^k The Oden Fish Hatchery in Michigan consumes 1,500 MWh of electricity each year. A 650 kW ground mount solar installation was completed in late 2020 to cover part of this demand.

A community interested in a co-development project associated with a CISF might favor behind-the-meter solar projects located at schools because of their cost-saving benefits to an important public service. The Kildeer Countryside School District 96 in Long Grove, Illinois, has a 100-kW solar project completed in fall 2020. The ground-mount solar system covers three acres and meets 92% of the Country Meadows/Woodlawn campus' electricity demand. The project cost \$3.7 million and reduced the district's electricity bills (Journal Staff 2020). Adjacent landowners opposed the project because they perceived it detracted from the area's rural aesthetic ("Solar Field Dispute Pits School District vs. Long Grove Horse Farm Owners, Residents" 2019). This illustrates the importance of social analysis for these sites.

Another example of behind-the-meter solar power serving a school is the Goshen Community Schools solar project at Model Elementary and Prairie View Elementary in Goshen, Indiana. The district pursued solar power to reduce its electricity bills (Kline 2019). The district worked with an Energy Service Company (or ESCO) called Performance Services, which specializes in solar and energy efficiency for school districts. In addition to renewable energy generation, the project included energy efficiency upgrades, improving temperature controls, and correcting uncomfortable temperatures impeding learning (Wede n.d.). Efficiency and cost-saving measures included new air handling units with digital controls, new refrigerants for cooling systems, high-efficiency boilers, chiller replacement, LED lighting, dual-pane windows, and new water heaters. Additionally, Performance Services installed two ground-mount solar arrays at Model and Prairie View Elementary Schools, totaling 795 kW at a cost of \$1.7 million (Kline 2019). Between the efficiency and clean energy initiatives, Performance Services estimates the district will save over \$1 million per year (Wede, n.d.).

There are numerous examples of solar projects serving local government buildings and emergency services. A local government considering consenting to a CISF might favor such a project as a co-development opportunity that benefits the local government and the taxpayers by reducing the cost of electricity at municipal buildings and potentially increasing the resilience of essential community services.

The Bronzeville Solar microgrid in Chicago, Illinois is a 750-kW AC solar array with 500 kW of battery storage plus electric vehicle charging, backup natural gas combined heat and power generators, and advanced grid control systems. The project also includes public Wi-Fi and LED streetlights ("VLV Development Completes 1.1 MW Solar Facility Serving Bronzeville Public Housing" 2020). The Department of Energy supported the project with \$4 million in grants (EERE n.d.). The total project cost is \$25 million (St. John 2022). The microgrid is in a community of color on the South Side of Chicago. It features resiliency benefits, particularly since the Bronzeville microgrid will be connected to an existing microgrid at the Illinois Institute of Technology. The microgrids can "island" or disconnect from the grid during a storm or cybersecurity event (Henderson 2020). The microgrid powers several services, including a Chicago Police and Fire Department headquarters, a public library, a public housing development (Dearborn Homes Community housing 600 residents), and a nursing home. It also provides electricity to several educational organizations: a military high school (Chicago Military Academy at Bronzeville), a charter school (Perspectives, Illinois Institute of Technology Math & Science Academy), the Illinois College of Optometry, and a private school (De La Salle Institute). The project is a partnership between ComEdison and VLV Development, a Black- and Veteran-owned and operated development company, which employed local workers to construct the grid (EERE n.d.).¹

Another option is the development of behind-the-meter solar power to support public housing—the administrative costs associated with public housing or reduction in electricity bills for public housing

¹ See video on EERE website.

residents. This can support local or federal (U.S. Dept. of Housing & Urban Development) government. Most gains of behind-the-meter or distributed solar power have not accrued to low-income residents, representing inequities in the deployment of clean technology (Gao and Zhaou 2022; Reames 2020; Miller et al. 2015; Sunter et al. 2019; Womble 2022).

Boulder Housing Partners (BHP)—the housing authority for the city of Boulder, Colorado—is a national leader in using behind-the-meter or community solar power deployment. BHP is a member of DOE’s National Community Solar Partnership, Multifamily Affordable Housing Collaborative (Stewards of Affordable Housing for the Future 2022). BHP has multiple projects reflecting several different models: behind-the-meter rooftop solar power for residents and administrative buildings and community solar power for residents. These different solar models total 2.6 MW of installed capacity or 40% of BHP’s energy demand (“Boulder Housing Partners: Solar at BHP” 2022).

BHP has deployed rooftop, behind-the-meter solar in the following applications:

- Rooftop solar on public housing: Half of BHP’s 37 properties are served by rooftop solar installations that reduce residents’ electricity bills (“Boulder Housing Partners: Solar at BHP” 2022). For example, BHP recently installed an 81-kW solar array that supports an energy-efficient 35-unit housing complex (Palo Park) with electricity and EV charging (BHP 2018).
- Rooftop solar for administrative building: With support from DOE funding from the Resilient Energy Delivery Infrastructure initiative, BHP has also installed solar modules on their office building headquarters, including battery storage, electric vehicle charging, a natural gas generator, and smart controls (“Boulder Housing Partners” n.d.). The project cost \$143,476.

BHP has also installed community solar:

- Community solar: BHP also has five ground-mount community solar gardens, which are not all located on the same site as their housing projects and are not behind-the-meter. Community solar has advantages for some low-income housing stock, which does not always have rooftops suitable for supporting solar systems (Longo Better 2022). Through BHP’s community solar projects, residents are subscribed to a solar program, reducing their electricity bills even though the electricity itself simply feeds into the grid (Stewards of Affordable Housing for the Future 2022).

One of BHP’s recent solar projects, built in 2020 by a nonprofit called GRID Alternatives, is a 21-kW solar garden on 3.8 acres supported by American Recovery and Reinvestment funds (BHP 2020). The organization specializes in installing solar projects for affordable housing organizations and low-income residents. GRID Alternatives employed tribal construction workers who had been affected by the COVID-19 pandemic. BHP anticipates that the project will save \$647,237 over 20 years, which the organization will use to reduce operating expenses and lower some residents’ utility bills.

While solar projects for affordable housing offer numerous advantages for social equity, barriers such as lack of trust, linguistic isolation, and administrative burdens can hamper residents’ participation (Stewards of Affordable Housing for the Future 2022). Careful planning is needed to avoid such pitfalls.

Municipal water treatment facilities offer another siting option for behind-the-meter solar installations that provide community-wide benefits. The City of Plano, Illinois’ 1.1 MW solar system built in 2019 supports its water treatment plant. Funding from Illinois state’s Adjustable Block Program under the Future Energy Jobs Act supported the project (“City of Plano Solar Farm ‘Energized’ and Fully Operational” 2021). Sixty-five percent of the electricity covers the municipal water treatment plant’s operations. The project is expected to reduce carbon dioxide emissions by over 8,484 metric tons. The system is partly rooftop and partly ground-mount, located on previously vacant land next to the water treatment facility. The behind-the-meter system is also grid-tied. It will result in energy cost savings and will provide 1,600 Solar Renewable Energy Credits annually (“The Plano Project” n.d.).

Behind-the-meter solar installations at water treatment facilities can offer opportunities for dual land-use if the arrays are sited on the water. Solar company Ciel et Terre developed Windsor, California's 1.8 MW floating solar array on four acres of one of the town's water treatment ponds (Borja 2022). It provides electricity to the water treatment facility, formerly the source of 45% of the town's greenhouse gas emissions, and to the town's public works building (*ibid.*). The city expects to save \$175,000 annually from the installation.

The solar company White Pine Renewables completed the Healdsburg Floating Solar Project in 2021 at a wastewater treatment facility in Sonoma County, California. The facility processes raw sewage into clean water for irrigation (City of Healdsburg 2021). The solar array floats on two wastewater treatment ponds. Land availability is limited and expensive in the county because most of the land is used to grow grapes for the wine industry. Floating solar is more expensive but has the added benefit of reducing algal growth and evaporation. Reducing the algal growth improves the water quality for irrigation of the vineyards. The partnership with a private company enables taking advantage of the federal tax credits. The solar installation provides 8% of the city's electricity needs (ABC7 2022).

The following sections use examples from the case studies to discuss the costs and benefits of behind-the-meter solar installations that might be experienced by a local host community.

A-1.2 Utilities and Resource Use

Behind-the-meter solar installations provide electricity that benefits public services. When paired with building energy efficiency measures, such projects can reduce energy demand while meeting the remaining demand with clean energy.

Water use for solar photovoltaics is lower than most energy technologies. In dusty climates, some water is used for washing the panels and spraying the ground to reduce module soiling, ensuring that dust does not significantly reduce the electricity generation (Hernandez et al. 2014). For monocrystalline solar modules, Fthenakis and Kim (2010) estimate the average water usage is 0.019 m³/megawatt hour. In less dusty areas (with high rainfall or vegetation that reduces dust), module washing may be unnecessary. Photovoltaic production requires some water consumption; for example, the silicon wafers and glass must be washed during the production process (Fthenakis and Kim 2010). This lifecycle water usage varies based on technology type (e.g., monocrystalline versus cadmium telluride modules).

A-1.3 Environment

Solar microgrids and behind-the-meter solar power decrease CO₂ emissions. For example, the Blue Lake Rancheria Tribe's microgrid in California is estimated to reduce greenhouse gas emissions by 200 tons per year and saves the Tribe \$200,000 per year in utility costs (Wilson, 2020). Additionally, the Bronzeville microgrid is reducing greenhouse gas emissions not just through clean energy but also through related energy efficiency measures (ComEd n.d.).

Solar generation is low carbon during the manufacturing and generation phases. Overall, NREL estimates from combined greenhouse gas emissions studies in the literature that solar PV emits approximately 40 grams per CO₂ equivalent per kWh, compared to 1,000 for coal (NREL 2013). Most (60—70%) of this is emitted in the manufacturing stages (*ibid.*). Another environmental consideration is the disposal of the modules at the end of their 25-to-40-year lifespan. By 2050, the waste stream for solar modules is anticipated to be between 60 and 78 metric tonnes (Weckend, Wade, and Heath 2016). While more research is needed, the existing scientific literature indicates that there are limited issues with solar modules leaching into landfills (Sinha et al. 2020). The concerns vary by solar technology, with some concerns related to leaching of lead from crystalline silicon modules that use lead solder and pastes (Collins and Anctil 2017). Recycling of modules is costly because they are encased in tempered glass, impeding access the raw materials (Sinha et al., 2020). Module recycling is uncommon in the U.S. However, the E.U. requires companies to cover the costs of recycling upfront (Weckend, Wade, and

Heath 2016), and some U.S. states are considering similar legislation (Habib 2017; “Solar Panels” n.d.). Project implementers can alleviate concerns that the modules will not be removed from the solar site at the project’s end by requiring a decommissioning plan and placing decommissioning costs in escrow upfront.

Local environmental effects from solar power depend on the type of land used e.g., greenfield, brownfield, rooftop, or floating. Greenfield projects can have some adverse effects on wildlife habitats, although these effects can be mitigated through initiatives such as using wildlife fencing (which does not increase project costs), improving vegetation under the arrays, and adding bird perches (Aman et al. 2015; Hernandez et al. 2014; Moore-O’Leary et al. 2017). Brownfield projects avoid consuming wildlife habitat and reuse land. Still, they are typically higher cost. (Spiess and de Sousa 2016). Floating solar PV avoids consuming land that could be developed for other purposes and can reduce algae growth and evaporation. However, it is more expensive than a ground-mount system and could affect aquatic life and interfere with recreational uses or aesthetic values of the aquatic environment (Armstrong et al. 2020).

A-1.4 Recreation and Tourism

For ground-mount solar installations, numerous creative opportunities are available to beautify the space and add recreation opportunities. For example, the 750-kW Solar Strand project at the University of Buffalo, which is part art and part energy generation, features walking paths through the solar arrays (Hill n.d.). The modules are arranged in the shape of a strand of DNA. People walking on the paths are invited to look up at the tallest arrays, which have the effect of an infinity pool (Hill n.d.). The project provides a direct, interactive experience with clean energy generation and is designed to make the university’s commitment to sustainability visible. Such a project could attract visitors and put the CISF host community on the map for reasons aside from spent nuclear fuel storage, alleviating stigma. If the host community is situated along an interstate, billboards could advertise the project, which could be located near restaurants and other businesses to generate induced economic benefits.

An array with a standard layout could also offer recreational opportunities. In addition to walking paths through the arrays, the land around the array could be improved. In a project being planned in Lansing, Michigan, a large grassy field next to a community center will feature a solar array with improvements to the adjacent grassy space such as dog relief stations and playground equipment (Figure A-2). The nearby track, which the community uses frequently, needs repairs and will be resurfaced. In addition, aesthetically appealing landscaping, pollinator plantings, or even fruit or vegetables can be grown under the arrays to improve aesthetic benefits. For example, Jack’s Solar Garden in Colorado is a 1.2 MW solar installation where crops are being grown under the arrays (Jack’s Solar Garden, LLC n.d.).

Figure A-2. Lansing, Michigan Southside Community Center, area with planned ground-mount solar project and improved recreational space. Photo by Sharlissa Moore.



A-1.5 Socioeconomic

Providing direct revenue by reducing the cost of electricity for local government and other community services is the most apparent benefit of behind-the-meter solar projects. With the falling cost of solar power in recent years, these projects pay themselves off even in cloudy regions of the country (Bazilian et al. 2013). For example, the Kildeer school district project in Illinois will save \$6 million in utility costs over 20 years and \$9 million over 30 years (Shields 2019). Furthermore, the district values the consistent energy rates for financial planning and increased operational funds (ibid.). The project and building energy efficiency initiatives at the Goshen Schools in Indiana are expected to save the school district over \$1 million per year (Wedde, n.d.).

Public entities and nonprofit organizations cannot take advantage of the tax credits associated with solar development. Therefore, most of these entities contract with a private company to develop the system and reap the financial benefits through a lower electricity rate. In some jurisdictions, utility rebates and renewable energy credits are available (KCS District 96, 2021). DOE would likely want to institute a public-private partnership to proceed with this co-development opportunity.

Overall, in 2020, there were 317,000 solar workers in the United States, with 165,000 in construction, 49,700 in pro services, and 41,900 in manufacturing (U.S. Department of Energy et al. 2021). Job creation for small solar projects is unfortunately limited, with some construction or installation jobs and few operations and maintenance jobs (Solar Energy Industries Association et al. 2021). Construction typically only takes several months. Ideally, the developer would hire local electricians and other trades to maximize local benefits. For this type of solar development, creating sustained job opportunities would require building multiple projects within a region. This could include rooftop installation, as often companies that develop behind-the-meter solar projects also sell residential systems. Of U.S. solar installation jobs, 55% are residential, and 8% are for community solar (including behind-the-meter) (ibid.).

Other workforce development opportunities may include hands-on learning and training opportunities at established solar sites and increased career pathway visibility in the community. Even though solar may not provide sustained jobs during the construction and operations and maintenance phases, a local organization or school may be able to leverage the site to enhance their job training programs. As an example, the developer for the Bronzeville microgrid project received state funding through the Illinois Future Jobs Act by incorporating training for 35 solar workers (Cohn 2019).

A-1.6 Community Wellbeing

Behind-the-meter solar power at municipal buildings or within a neighborhood can improve grid resilience through peak shaving (i.e., supplying electricity from solar power during hours of peak demand) or battery storage. During off-peak hours of demand, surplus electricity generation from solar power (or other sources) charges the batteries for use during on-peak hours of demand or outages. While solar power is economically feasible, the addition of battery storage and microgrid capabilities typically requires grant money or charitable contributions. Additionally, technoeconomic analysis is needed for the planning and design of the microgrid (Lu et al. 2015).

The Urban Sustainability Directors Network defines community resilience hubs as “community-serving facilities augmented to support residents, coordinate communication, distribute resources, and reduce carbon pollution while enhancing quality of life” (<http://resilience-hub.org/>). An example would be a solar and battery installation at a community center that serves as a heating or cooling center for residents during a power outage. Residents could also use the electricity for refrigerating medication, operating medical devices, and charging cellular phones. During a disruption, hubs could also provide childcare, housing for pets, potable water filling stations, mental and physical health resources, and baby formula and food storage (“Core Components” 2019). A hub could also focus on first responder services, such as fire and police, as well as a 9/11 dispatch center (ibid.). In Northern California, a \$6.3 million solar-powered

microgrid run by the Blue Lake Rancheria Tribe at the Blue Lake Casino and Hotel provided essential services to a rural area during a power outage caused by wildfires (Wilson 2020). The services included housing for eight critical care patients, a makeshift newsroom for the local newspaper, and other services that benefited an estimated 10,000 residents (Wilson 2020).^m Additionally, the Boulder Housing Partners office building solar and storage installation was built for after the 2013 flooding to avoid future outages (Clean Energy Partners, n.d.).

The Bronzeville project, supported by DOE's Office of Electricity Delivery and Energy Reliability, focused explicitly on resilience gained through battery storage and the connection of two microgrids that can island (disconnect) from the centralized grid during disruptions. DOE's program objectives include reducing outage times, lowering emissions, and improving system energy efficiency (Lu et al. 2015). The project extends beyond a single building across several neighborhoods and a college campus in the south side of Chicago (Lu et al. 2015). The National Center for Disaster Preparedness led a desktop training exercise for the Bronzeville microgrid focused on a scenario in which a derecho (or inland windstorm) followed by extreme heat and humidity caused widespread power outages. They found that benefits included maintaining first responder operations, running emergency shelters, and enabling businesses to provide critical resources and avoid significant negative economic impacts (Schlegelmilch et al. 2021). Community and government participants noted that they needed more education and training to understand how to maximize use of the microgrid's capabilities (ibid.).

Solar at school sites provides educational benefits. For example, the Kildeer district is incorporating the project into their STEM curriculum (KCSO District 96, 2021). Signage can provide overall public education including educating people about how solar energy works or tracking the output of the solar installation and greenhouse gas emissions avoided (Semmler 2021).

Figure A-3. An example of an educational sign at a community solar installation in Detroit, Michigan. Photo by Sharlissa Moore.



^m The project was funded with a \$7.5 million award from the New York Power Authority. It opened in 2013 and was designed by architect Walter Hood from the University of California, Berkeley (University at Buffalo Libraries n.d.)

As discussed in the case study description, the Boulder Housing Partners' projects and the Bronzeville Microgrid focused partly on reduced utility bills for public housing. Over the project's lifespan, the Chicago Housing Authority is expected to save \$800,000 from a 1.1 MW solar installation ("VLV Development Completes 1.1MW Solar Facility Serving Bronzeville Public Housing" 2020).

Artwork can be incorporated into behind-the-meter solar installations. For example, at the Kildeer School District, art teachers led 32 young artists in drawing Illinois Prairie animals that are screened onto 100 modules (Kildeer, 2021). Partnerships between children and adult artists can draw increased attention to the multi-generational aspects of clean energy and sustainability.

The Bronzeville microgrid includes a solar-powered pyramid made by the artist "Shala," a Nigerian American artist who lives in Chicago (D'Souza n.d.). The pyramid focuses on renewable energy awareness and the cultural prominence of Bronzeville, known as Chicago's Black Metropolis (ibid.). The project's construction included students of color, who learned about STEM through the arts. The 16-ft pyramid consists of solar panels and solar-powered lighting. It is permanently on display in Gallery Guichard's Great Migration Sculpture Garden in Bronzeville. The solar electricity will cover the cost of the installation over time and generate revenue for community improvement (ibid.).

A-1.7 Equity and Environmental Justice

Significant racial and ethnic inequities exist in access to solar power across the United States (Sunter, Castellanos, and Kammen 2019). The Bronzeville project stands out as supporting a community where three-quarters of residents are Black. The neighborhood is known as Chicago's Black Metropolis because of its history as "an economic and cultural hub" for the African American community ("Bronzeville: The 'Black Metropolis' of Chicago" 2020). The neighborhood has a higher unemployment rate, lower income, and less retail availability than the rest of Chicago ("Bronzeville Context" n.d.). Chicago-based VLV Development, a Black and Veteran-owned business, worked with local community members initially opposed to the project to incorporate a mural called "The Renaissance" on the battery storage units (which some community members found unsightly). The mural focuses on the neighborhood's history and future, incorporating African American iconic figures, such as Ida B. Wells ("New Mural Tells the Story of Bronzeville" 2020). The focus on powering public housing adds an equity dimension to the project (Cohn 2019). VLV received state funding through the Illinois Future Jobs Act by incorporating training for 35 solar workers (ibid.). The included electric vehicle charging is partly for a rideshare service that provides residents of a senior housing facility with low-cost rides to local stores (Henderson, 2020).

Overall, behind-the-meter solar projects can improve social equity through a variety of measures including hiring local workers and companies owned by people of color or indigenous people, reducing electricity bills for low-income residents, alleviating electricity bills for municipal services to benefit taxpayers, improving resilience for underserved neighborhoods, and integrating the installation into the history and fabric of the community through artwork and other design features.

A-1.8 Government Benefits

With planning, behind-the-meter solar offers various benefits to federal government missions.

- Solar for low-income housing or municipal government services could support Justice40 goals if the CISF is developed in a community that CEQ's Climate and Economic Justice Screening Tool identifies as underserved.
- DOE's Office of Electricity Delivery and Energy Reliability and the Resilient Energy Delivery Infrastructure initiative: The office funded the Bronzeville microgrid to meet its mission of ensuring the delivery of secure, resilient, and reliable electricity (<https://www.energy.gov/oe/office-electricity>).

- EERE's/SETO's National Community Solar Partnership, Multifamily Affordable Housing Collaborative supports the development of community solar power, including for public housing (<https://www.energy.gov/communitysolar/community-solar>).
- Behind-the-meter solar power meets the goals of Executive Order 13990 "Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis, which calls for federal agencies to evaluate their recent actions related to climate change and to prioritize reducing climate change impacts and address EJ where the federal government has failed in the past.
- Behind-the-meter solar power that meets the needs of local communities fits into the mission of the new DOE Office of Clean Energy Demonstrations, which is focusing on place-based energy innovation, intertwining clean energy and energy justice goals (<https://www.energy.gov/office-clean-energy-demonstrations>).

The benefits to local government center on cost savings for utility bills, meeting renewable energy goals, and the prestige of advancing renewable energy (many of the projects discussed here have won awards). The benefits of meeting renewable energy goals and prestige also accrue to the state level.

A-2. Greenspace Development

A-2.1 Description of the Development Opportunity

Greenspace development is a broad category that includes a range of environmental outcomes and improvements such as ecological restoration, wildlife habitat restoration, ecosystem services enhancement, recreational access, land conservation, and more. Selected case studies have been assessed that illustrate a range of potential co-development opportunities in the "greenspace development" sector for communities hosting a CISF and potential impacts within the following sub-categories; although opportunities in this space are vast and will depend upon the priorities of the community (or communities) in which they are implemented, as well as available resources such as available workforce, training programs, and supply chain.

A-2.2 Utilities and Resource Use

The cases presented in this section did not make direct connections between greenspace development and resource use; however, environmental improvements, such as floodplain restoration, offer clear benefits to water use and water quality (Watson et al. 2016). Additionally, place-based design of renewable energy projects has the potential to enhance natural capital by envisioning multifunctional landscapes that prioritize clean energy infrastructure and environmental resilience, thus contributing in multiple ways to local value for rural communities (O'Neil et al. 2022). Conservation and resource use are often perceived as conflicting, but recent analyses highlight the potential for complementarity between renewable energy design and conservation objectives (Jager, Efroymson, and McManamay 2021). Greenspace development in rural communities as part of a consent-based siting process may offer unique opportunities to demonstrate innovative clean energy design as part of the natural landscape.

A-2.3 Environment

Greenspace development supports the enhancement of ecosystem services, which contribute to community well-being (Summers et al. 2012). Opportunities for greenspace development, especially in the form of conservation or habitat restoration, can enhance available ecosystem services. For example, restored wetlands and floodplains can mitigate flood damage along rivers for downstream communities, as well as provide habitat for wildlife, enhance recreational opportunities, and improve water quality, as demonstrated in the case of Otter Creek, Vermont (Watson et al. 2016). Following the Otter Creek floodplain restoration project upstream of Middlebury, VT, an economic analysis determined that the restored floodplain mitigated peak discharge from Tropical Storm Irene in 2011 and saved the town over \$1.8 million in damages. Continual monitoring has found the annual value of flood prevention services of

the restored riparian landscape to range from \$126,000 to \$450,000, illustrating the socioeconomic and environmental value of ecosystem services. Further, community members tend to place a high value on ecosystem services and prioritize conservation objectives when presented with a diversity of development options (Mueller and Tickamyer 2020).

A-2.4 Recreation and Tourism

Greenspace development contributes directly to recreation and tourism by providing land access opportunities and supporting jobs for maintenance, management, and land enhancement activities. Additionally, outdoor (and especially nature-based) recreation can lead to greater place attachment and positive affiliation with local landscapes (Kyle et al. 2003). For example, recreational and tourism concerns were highly prioritized in a collaborative, community-based development project in rural Colorado (Garfield Legacy Project 2012). Residents of rural Garfield County, CO, were invited to participate in a strategic conservation and economic development assessment, which found that residents' values and concerns for development priorities emphasized actions that would enhance working farms and ranches, support recreation tourism, preserve open lands around communities, conserve water supplies, enhance trail systems, and protect wildlife habitat.

Moreover, recreation and tourism are integral public resources that enhance the quality of life for rural residents and visitors alike (Pedlar 1996). This is especially important during times of uncertainty and stress, such as that experienced during the Covid-19 pandemic beginning in 2020. Rice et al. (2020) observed drastic reductions in frequency of outdoor recreation participation and distance traveled for recreation in response to Covid-19 related restrictions. However, urban residents exhibited much greater changes in recreation behavior than rural residents, illustrating the importance of available greenspace for recreation and the need for nature-based coping mechanisms to alleviate psychological and physiological stress (Powell, Thomsen, and Allen 2013).

A-2.5 Socioeconomic

Greenspace development, when paired with socioeconomic monitoring, can highlight connections between ecosystem services and economic benefits that are often unaccounted for by traditional economic metrics. Additionally, the outdoor recreation economy has been valued at more than \$400 billion annually (Bureau of Economic Analysis 2017), the benefits of which accrue to local communities in myriad ways that are difficult to measure.

For instance, a large, collaborative restoration project of an ecologically damaged oyster reef on the gulf coast, TX, led to a multi-tiered study on the social, economic, and ecological impacts resulting from restoration of the damaged reef (Carlton, Ropicki, and Balboa 2016). After the successful completion of the restoration project, there has been enhanced commercial harvesting of oysters, greater coastal resilience, increased recreational fishing, and increased marine biodiversity. Additionally, anglers using the reef for fishing have added \$691,000 to Texas' GDP annually and generate over \$1.2 million in economic activity. The reef supports several new jobs with \$465,000 in annual labor income (Carlton, Ropicki, and Balboa 2016).

This case illustrates an integrated approach to environmental restoration and socio-economic monitoring that can be applied to co-development opportunities in the consent-based siting context. Restoration projects such as this can be critical to the future of rural and/or coastal landscapes and livelihoods and are likely to be highly valued by community members.

A-2.6 Community Wellbeing

Community wellbeing is a multidimensional construct with indicators that span several social, cultural, economic, and psychological domains (Christakopoulou, Dawson, and Gari 2001). In the context of greenspace development, wellbeing might be considered as socio-ecological assets that contribute to the

resilience of a community. In that sense, the value structure and priorities of a community in relation to proposed development might provide a measure of community wellbeing (Cavaye 2001).

Greenspace development in rural communities should consider ways in which conservation and economic development priorities can be “value-stacked” to create multiple benefits for communities that align with their values for social and environmental outcomes, thus improving community wellbeing. Understanding the socio-demographic composition of the community is likely important when determining which opportunities are most relevant. Knowing the primary economic drivers (e.g., resource extraction-based vs. recreation, tourism, or other service-based, etc.), the age structure of the community, and the relative proportions of long-term residents to newer residents will help determine how to approach economic or environmental development goals (Ulrich-Schad et al. 2022). Additionally, knowledge of the financial (in)security of individuals and the community as a whole can help better predict preferences for environmental and economic development opportunities.

It is important to note, however, that focusing on outcomes alone is likely to be an unsuccessful approach; In a study of rural Pennsylvania residents, support for community development opportunities (including renewable energy and outdoor recreation) was strongest when residents perceived that the development would have positive impacts in the community, when they had greater trust in the industry to do the right thing, and when they had some level of agency during the decision-making process (Mueller and Tickamyer 2020).

Greenspace development projects are unlikely to have significant impacts on emergency services, traffic, and housing, all of which affect the livability of a community. However, there may be benefits in other areas. Schools and students may have access to new nature-based learning opportunities. Public health and mental health may be supported with improved access to nature, parks, and recreation areas. A project which addresses hazards such as flooding improves a community’s resilience to weather events.

A-2.7 Equity and Environmental Justice

Experiences in nature provide people with multiple physical, mental, and social benefits (Kellert et al. 2017; Louv 2008; Holland et al. 2018). Those benefits, however, are not allocated equally to all communities. Outdoor recreation research has established that people of color are less likely to use parks and recreation facilities or conservation areas and have fewer opportunities to engage in leisure pursuits (Lee, Casper, and Floyd 2020; Outdoor Foundation 2020). There are multiple opportunities through greenspace development to enhance equitable access to benefits derived from ecosystem services, natural amenities, outdoor recreation, parks and recreation facilities, etc. This might be accomplished by inclusive programmatic design, youth programs, segmented communication efforts tailored specifically to audiences of diverse cultural and ethnic backgrounds, prioritizing diversity, equity, inclusion, and justice initiatives at the administrative level, and conducting research and monitoring to determine the best ways to facilitate broader demographic usage of greenspace.

A-2.8 Infrastructure

Infrastructure improvements might result from development of greenspace by improving public access to conservation areas, trail development, improved roads to accommodate increased visitor pressure, and park signage or other miscellaneous infrastructure improvements that facilitate positive visitor experiences (e.g., boat ramps, pavilions, restrooms, campgrounds, etc.).

A-2.9 Government Benefits

Greenspace development opportunities have a high potential to align with federal, state, and local government missions. Federal opportunities include alignment with objectives of the Justice40 Initiative and other environmental justice efforts laid out by the Biden administration (White House 2021). Ecosystem services delivered by restored or conserved habitat near host communities helps mitigate potential damages stemming from a changing climate, and careful development of greenspace can help

ensure that the immediate benefits of access to nature as well as the long-term social and ecological impacts from fighting climate change are allocated to underserved communities. Additionally, greenspace development may qualify host counties as “recreation counties”. The U.S. Department of Agriculture’s Economic Research Service has detailed analyses on recreation counties and the associated benefits (e.g., increased in-migration, higher incomes, varied economic benefits, etc.) of the recreation county designation (Headwaters Economics 2019).

At the state and local level, various initiatives exist across the country to grow the outdoor recreation economy. According to the Outdoor Industry Association (2019): “To date, 16 states have created offices of outdoor recreation, task forces, or policy advisors to serve as the state lead in bolstering economic development and the outdoor recreation economy; promoting health and wellness; ensuring conservation and stewardship of public lands and waters; educating and engaging children in the outdoors; and serving as a point of contact to the businesses, stakeholders and different levels of government that care about the outdoor recreation industry”.

A-3. Science and Technology Park

A-3.1 Description of the Development Opportunity

Science and technology parks (STPs) are typically developed with the objective of facilitating research, manufacturing, and start-up incubation. Businesses are located in close proximity to one other and benefit from cross-pollinating of innovative ideas, collaboration, and cost savings. Often an STP is affiliated with a university (in the case of Tecnocampus in Spain, Research Triangle Park in North Carolina, and Stanford Research Park in California) or with a government mission (as in Sandia Science & Technology Park affiliated with Sandia National Laboratories, or a proposed technology park in Italy in conjunction with a radioactive waste disposal site). These parks have emerged around the world advertising benefits such as increased economic development, faster innovation, and a better quality of life. For these reasons, co-locating government and/or university facilities with private industry may be an attractive co-development opportunity for a community seeking sustainable long-term growth.

A few case studies were selected as examples illustrating the science and technology park co-development opportunity. One case study involves co-development of a science and technology park alongside a national disposal facility for radioactive waste in Italy. While this project is still in the planning phase and has not yet been sited, the facility design documents shed some light on how a science and technology park might influence the local environment, resource use, recreation and tourism, and impacts in other areas.

Another relevant case study used to illustrate impacts is an economic impact assessment of Sandia Science & Technology Park, located in Albuquerque, New Mexico. The Park is associated with Sandia National Laboratories (SNL) and is near Kirtland Air Force Base. An economic impact assessment of the Sandia Science & Technology Park (SS&TP) is conducted every 2 years by the Mid-Region Council of Governments at the request of the City of Albuquerque (Kolberg 2020). The most recent assessment, completed in 2020, reports direct and indirect socioeconomic impacts such as jobs and revenue; community wellbeing considerations like housing, schools, and parks; infrastructure improvements; and government benefits.

Still other case studies and analysis are used to fill in additional detail on different ways STPs might be positioned to benefit a community, such as research on the impacts of Tecnocampus in Spain (affiliated with Pompeu Fabra University) which promotes business incubation and entrepreneurship, and (Torres-Pruñonosa, Raya, and Dopeso-Fernández 2020), and an analysis which explores a variety of applications in Indonesia including capitalizing on local talent and creating innovative products from local resources (Kusharsanto and Pradita 2016).

A-3.2 Utilities and Resource Use

Science and technology parks can be heavy users of energy and water resources, particularly where offices, data centers, and manufacturing are involved. Manufacturing accounts for 28% of all energy use in the United States (Energetics Incorporated 2012). Data centers use water for cooling and electricity generation (Mytton 2021). Offices depend on electricity for equipment such as computers and printers, as well as for lighting, heating, and cooling (U.S. Energy Information Administration 2018). Newer facility designs are incorporating sustainability and efficiency principles and technologies, with the objective of reducing demand on existing infrastructure and scarce resources (Cummo et al. 2016).

Italy's proposal for siting radioactive waste and spent fuel includes co-locating a science and technology park and emphasizes sustainable systems. Incorporating technical and nanotechnology systems, the buildings are designed to filter pollutants in the air, reduce water consumption through rainwater recovery and storage systems, and capture solar radiation with PV panels. Buildings are classified as Nearly Zero Energy Buildings, with PV designs estimated to supply 40% of the energy load to the park. Building materials are selected in accordance with environmental sustainability criteria, and in conjunction with maintenance procedures are guaranteed for a high level of energy efficient performance (Cummo et al. 2016).

STPs have a footprint that often utilizes many acres of land. Italy's design sections off 40 hectares (about 100 acres) for current development with space for future expansion (Cummo et al. 2016). Sandia Science & Technology Park utilizes over 300 acres of land (Kolberg 2020). Spain's Tecnocampus has a built area of 50,000 square meters (about 12 acres) (Torres-Pruñonosa, Raya, and Dopeso-Fernández 2020). Even with careful design considerations, it is likely that large areas of land will be needed to allow for new development and future growth.

A-3.3 Environment

The environmental impacts of science and technology parks are focused on resource consumption and land use, but there are other effects which may be felt at a smaller scale. Italy's co-development technology park concept is based on environmentally sustainable design criteria which limits the environmental impact of structures. An air-cleaning photocatalytic paint is proposed for all buildings, claiming a "significant contribution" to air quality. Water use is minimized through a rainwater recovery system. Runoff from impermeable surfaces is captured and recycled for irrigation and sprinklers, and a pond at the center of the design provides a natural habitat for plants and animals as well as functioning as an emergency reserve for the fire extinguishing system. Landscape plants are selected from native plants to replicate the natural habitat. Recycling is planned to be taken to a collection center (Cummo et al. 2016).

Land used for a science and technology park will not be available for other uses such as greenspace, agriculture, or recreation. Land impacts are somewhat mitigated in Italy's plan through building design which minimizes foundation excavation. This ensures an easier return to the natural state if buildings are removed (Cummo et al. 2016).

A-3.4 Recreation and Tourism

Tourism may experience adverse impacts associated with locating radioactive waste in an area due to public concerns and the image of the area. Science and technology parks themselves may not be a draw for recreation and tourism to offset this, but it is not uncommon to have a nearby museum or other facilities that may draw visitors. The Sandia Science & Technology Park is in close proximity to the National Museum of Nuclear Science & History, which draws visitors from the U.S. as well as internationally (Kolberg 2020). Italy's design places an emphasis on tourist attractions that may be located within or near the science and technology park. Plans include restaurants, hotels, a science museum, sports facilities, an outdoor amphitheater, sensory pathways and a play area for children, an auditorium, an academic center, and an electric rail system (Kolberg 2020).

A host community may benefit from a reduction in potential stigma effects and increased tourist activity if a co-developed science and technology park incorporates some or all of these complimentary facilities.

A-3.5 Socioeconomic

The benefits of a science and technology park to a host community are most apparent in increased economic activity, revenue, and jobs. If co-developed with an interim storage facility, an STP could provide stability in revenue and jobs beyond the CISF life cycle.

Jobs directly attributable to an STP pay higher than average wages (Kolberg 2020) and reduce over-education leading to improved job satisfaction and performance as well as better matching between graduates and businesses (Torres-Pruñonosa, Raya, and Dopeso-Fernández 2020). Training centers are also often incorporated as part of an STP, offering training on innovation and entrepreneurship, startup training, technology, and machinery, leading to a skilled and competitive workforce (Kusharsanto and Pradita 2016).

Spain's Tecnocampus makes up 0.37% of total employment in the region, employing about 823 people (Torres-Pruñonosa, Raya, and Dopeso-Fernández 2020). At a larger scale, Sandia Science & Technology Park employed 2,369 people as of 2019 who earn a higher-than-average wage when compared to the Albuquerque Metropolitan Statistical Area. Notably, the SS&TP continued hiring skilled workers and showed a strong growth trend even as the surrounding area job market was shrinking (Kolberg 2020).

At SS&TP, most jobs (65%) fall under Professional, Scientific, and Technical Services. The second highest job category is in manufacturing with 27% of jobs.

Table A-2. Sandia Science & Technology Park 2018 and 2019 Employment by Industry Subsector (Kolberg 2020).

Industry Subsector	2018	2019
Fabricated Metal Product Manufacturing	4	4
Computer and Electronic Product Manufacturing	366	379
Electrical Equipment and Appliance Manufacturing	212	225
Miscellaneous Manufacturing	30	38
Telecommunications	3	3
Monetary Authorities, Credit Trust, and Other Financial Services	11	10
Professional, Scientific, and Technical Services	1,421	1,546
Educational Services	94	98
Social Assistance and Other Non-Profit Organizations	36	39
Museums, Historical Sites, Zoos, and Parks	16	26
Membership Associations and Organizations	1	1
Total	2,194	2,369

The SS&TP also draws investment from both public and private sources totaling \$5.7M in 2019. The Park was home to 48 companies as of 2019 (Kolberg 2020).

Indirect impacts on the economy are felt as STP employees spend their wages and in other business investments. The area surrounding SS&TP has experienced growth in restaurants, retailers, warehouses, and office buildings, and Albuquerque and New Mexico have gained a reputation as a desirable location for high-tech companies (Kolberg 2020). Economic impacts are felt throughout the region as shown in Table A-3.

Table A-3. Estimated Socioeconomic Impacts of the Sandia Science & Technology Park, 2019 (Kolberg 2020).

Measure	City of Albuquerque	Bernalillo County (area outside of the City of Albuquerque)	Mid-Region Council of Governments Region (Bernalillo, Sandoval, Tarrant, Valencia, and Southern Santa Fe Counties)
Impact on Total Employment	5,800	706	6,985
Construction	469	175	733
Manufacturing	607	27	642
Retail Trade	459	57	591
Professional and Technical Services	1,770	146	1,931
Health Care and Social Assistance	484	35	563
Accommodation and Food Services	319	28	383
Other Industries	1,692	238	2,142
Direct Employment (at the SS&TP)	2,369	0	2,369
Indirect Employment	3,431	706	4,616
Gross Regional Product	\$624,000,000	\$61,100,000	\$719,500,000
Wage and Salary Disbursements	\$407,300,000	\$35,200,000	\$457,000,000
Increase in Personal Consumption	\$271,700,000	\$56,000,000	\$405,700,000

A-3.6 Community Wellbeing

As shown in Table A-4, an STP brings population growth as workers and their families move to the area to work at the STP and to fill jobs which are created indirectly. As a result, there are likely to be associated impacts to resources and services which affect the community's quality of life. Greater demand will be placed on schools, housing, public health systems, parks and recreation facilities, and emergency services, among other aspects of quality of life. Science and technology parks create additional tax revenue which may be re-invested in public services and resources to offset some of this increased demand.

Table A-4. Estimated Population Impacts of the Sandia Science & Technology Park, 2019 (Kolberg 2020).

Measure	City of Albuquerque	Bernalillo County (area outside of the City of Albuquerque)	Mid-Region Council of Governments Region (Bernalillo, Sandoval, Tarrant, Valencia, and Southern Santa Fe Counties)
Impact on Population (2019 only, not cumulative)	1,583	316	2,467

If incoming workers bring drastically different levels of income and education or have a different social structure background from the host community, changes could result. Tensions could arise between established community members and incoming workers, and the character of the community could change (Guidi et al. 2009). Increased housing demand is a result of population growth, which could drive up home prices and rental costs. Increased traffic from construction and commuters results in longer drive times, more pollution, and more noise.

STPs can mitigate some of these impacts by incorporating intentional design and programs, and indirectly by stimulating economic growth and associated development. Italy's technology park design plans to host students from grade schools and their families, providing unique learning opportunities outside the classroom (Kolberg 2020).

An economic impact assessment of SS&TP estimates that more than 2,400 construction permits for new homes have been issued in the immediate vicinity since the park was established. There have also been improvements to a nearby community park, recreation facilities, and the Manzano Mesa Multigenerational Center and Elementary School (Kolberg 2020).

Italy's STP design and Sandia Science & Technology Park both incorporate features like walking trails, pocket parks, picnic areas, and exercise stations to improve the attractiveness and quality of life for the park and the area (Cumo 2016, Kolberg 2020). SS&TP is connected to the neighboring air force base and surrounding community via a bus route (Kolberg 2020).

Case study data does not directly address impacts to traffic, pollution and noise, emergency services, and public health systems. Impacts in these areas would need further analysis to present a complete view of effects in a community.

A-3.7 Equity and Environmental Justice

The case studies of science and technology parks offer no direct commentary on equity and environmental justice impacts. However, opportunities may exist to prioritize hiring from and provide training opportunities to community members who may belong to groups which have been historically marginalized and excluded from these types of opportunities.

Developers and planners should proceed with caution if proposing neighborhood revitalization projects (or projects that could indirectly influence this) as these could gentrify areas and push current residents out. This is a risk if higher income workers (or economic migrants) move to the area to take advantage of higher wage jobs available at a science and technology park. If pathways to employment are prioritized for current residents this risk could be mitigated.

If there are cultural differences between incoming workers and the existing community conflicts may arise (Guidi et al. 2009). Extra care may be needed to navigate the changing dynamics of the community.

A-3.8 Infrastructure

Assuming no actions are taken to improve infrastructure, negative impacts on infrastructure may be felt during construction and operations and as people move to the area for jobs. If designed to serve a smaller population, transportation, water and sewer, and grid resources among others could be strained by an influx of workers and their families. However, infrastructure improvements often take place at the science and technology park and benefits may be felt in surrounding neighborhoods.

For example, in addition to reducing strain on utility infrastructure through sustainable design, Italy's technology park design incorporates road improvements around the perimeter of the facility (Kolberg 2020). Sandia Science & Technology Park brings infrastructure improvement such as a fiberoptic network, park and landfill cleanup, storm sewer, and road improvements (Kolberg 2020).

A-3.9 Government Benefits

Benefits extending to local, state, and federal government include economic growth, collaboration between private companies and government, innovation, and increased tax revenue. STPs also provide an opportunity to commercialize innovation and local creativity (Kusharsanto 2016).

In the case of Sandia Science & Technology Park, Sandia National Laboratory (SNL) has direct access to industry via the park. SS&TP companies may supply goods and services to SNL, and close proximity and collaboration saves time and money. The Park is a convenient meeting place outside of security and access restrictions on the SNL campus (Kolberg 2020). Beyond Sandia National Laboratory, the SS&TP benefits state and local government through increased economic activity and tax revenue as shown in Table A-5 (Kolberg 2020).

Table A-5. Estimated Tax Revenue Impacts of the Sandia Science & Technology Park, 2019 (Kolberg 2020).

Measure	City of Albuquerque	Bernalillo County (area outside of the City of Albuquerque)	Mid-Region Council of Governments Region (Bernalillo, Sandoval, Torrance, Valencia, and Southern Santa Fe Counties)
Increase in Tax Revenue Generated from Personal Consumption to the State of Mexico	\$4,600,000	\$2,600,000	\$10,200,000

In Spain, Tecnocampus supports the economy's transition from an industrial economy to one that is knowledge-based and driven by innovation and entrepreneurship. Incentive structures established by political and economic institutions play a role in creating an environment that fosters growth and development. These policies promote quality employment and generate research products which contribute to economic activity (Torres-Pruñonosa, Raya, and Dopeso-Fernández 2020).

A-4. Small Modular Reactor Manufacturing

A-4.1 Description of the Development Opportunity

Small modular reactor manufacturing was selected to demonstrate the light manufacturing concept. Case studies outlining the specific socioeconomic benefits of individual advanced manufacturing businesses are not readily available. Due to limited case study data, an IMPLAN analysis was used to estimate utilities and resource use, environmental impacts, and socioeconomic impacts. The economic region analyzed was initially picked based on multiple criteria used to select suitable sites where nuclear power plants could replace coal fired power plants that were set for decommissioning. The location used in this analysis matches conditions that exists across the United States.

Economic benefits associated with advanced manufacturing would differ depending on its location, local supply chain, and labor force availability. For this report, impacts associated with this type of manufacturing were like what is found in metal fabrication or machine shop type businesses. These businesses would likely be part of building components used in small modular nuclear reactors and would further develop a nuclear industry cluster that might form around an interim waste storage facility. The estimated economic impact associated with the scenario provided in this report is based on a 150-employee manufacturing facility in a typical rural community with a combined multicounty population of around 80,000.

A-4.2 Utilities and Resource Use

Table A-6 provides an overview of estimated environmental impacts of a 150-employee advanced manufacturer. These estimates are derived from the IMPLAN input-output model combined with the Environmental Protection Agency's Environmentally Extended Input-Output (EEIO) Model.

Table A-6. Estimated SMR Manufacturing Utility and Resource Impact (Annual).

Impact Type	Mineral Use (Kg/Yr)	Water Use (Cu M)
Direct	0	49,453
Indirect	17,798	235,395
Induced	12,020	98,319
Total Impact	29,818	383,166

A-4.3 Environment

Table A-7 provides an overview of estimated environmental impacts of a 150-employee advanced manufacturer. These estimates are derived from the IMPLAN input-output model combined with the Environmental Protection Agency's Environmentally Extended Input-Output (EEIO) Model.

Table A-7. Estimated SMR Manufacturing Resource and Environmental Impact (Annual).

Impact Type	Criteria Pollutants (Kg/Yr)	Greenhouse Gases (Kg/Yr)	Land Use (Sq M)	Nitrogen & Phosphorus Release to Water (Kg/Yr)	Pesticide Emissions (Kg/Yr)	Toxic Chemical Releases (Kg/Yr)
Direct	3,661	458,586	60,740	0	0	0
Indirect	8,995	1,124,979	35,454	355	0	23
Induced	4,456	446,082	22,287	729	1	9
Total Impact	17,111	2,029,647	118,480	1,084	1	31

A-4.4 Recreation and Tourism

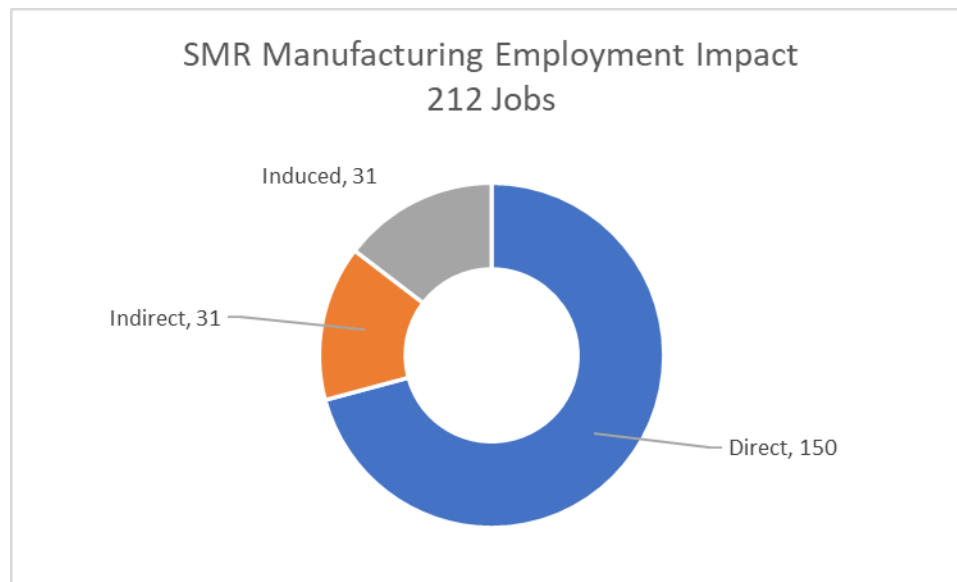
Small modular reactor manufacturing is unlikely to generate any effects on recreation and tourism.

A-4.5 Socioeconomic

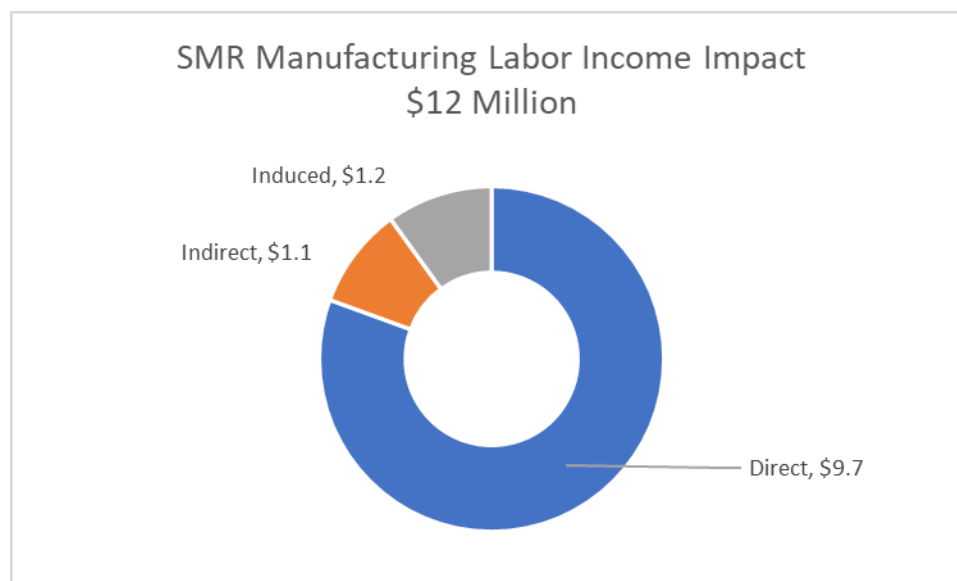
Impacts are broken down into the following categories:

- Direct: Initial impacts resulting from operations at the small modular reactor facility
- Indirect: Impacts that stem from local supply chain activity that supports the small modular reactor facility
- Induced: Impacts associated with direct and indirect employers providing income to workers and is then spent within the local economy based on typical household spending patterns

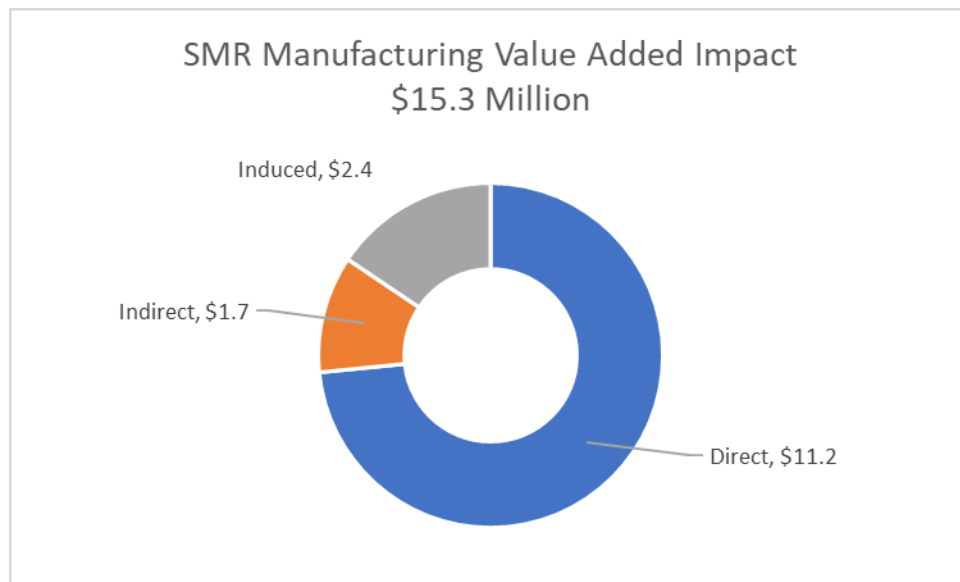
Employment impacts associated with a potential manufacturing facility begin with 150 workers directly employed by the facility. Business operations from the facility would create or sustain an additional 31 jobs among supply chain related business and 31 more jobs throughout the community as employee spending occurs. The combined employment impact would create or sustain a total of 212 jobs. These jobs are not recognized as full-time equivalent number of workers but as a count of unique jobs.

Figure A-4. SMR Manufacturing Employment Impact.

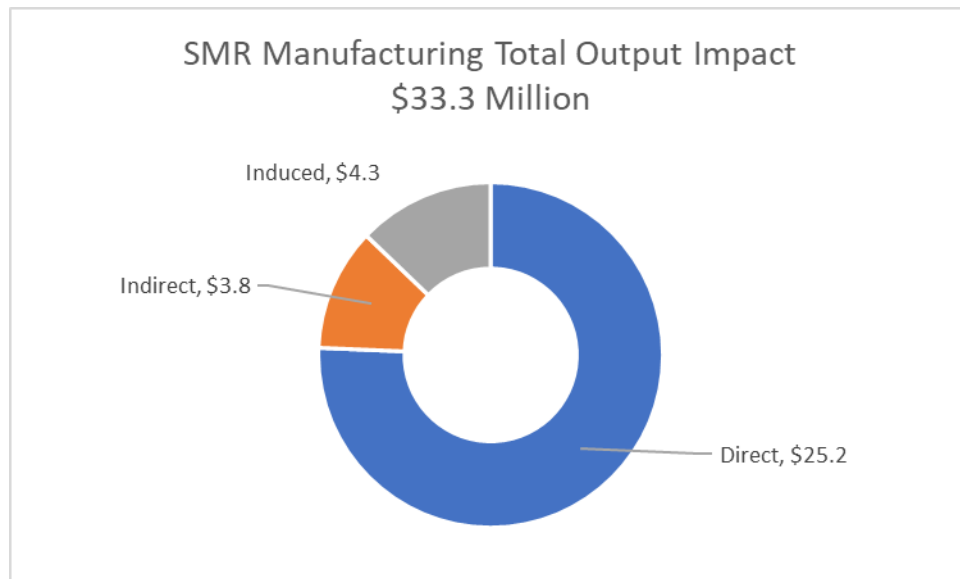
Job creation from SMR related or advanced manufacturing leads to new income for the region. Labor income associated with this scenario includes all wages, salaries, benefits, and taxes (employer and employee side). New labor income associated directly with SMR manufacturing facility operations could reach \$9.7 million. Indirect and induced labor income would contribute an additional \$1.1 and \$1.2 million respectively. Combined, all three sources of labor income would almost reach \$12 million annually.

Figure A-5. SMR Manufacturing Labor Income Impact.

Value added impacts from an SMR manufacturing facility would likely reach a total of \$15.3 million annually. These value-added impacts represent the region's contribution to gross domestic product, or the value of new production that occurs because of SMR related manufacturing activities. Nearly \$11.2 million of the value-added impact comes from the manufacturing facility itself with the remaining \$4 million balance coming from new supply chain activity and household spending.

Figure A-6. SMR Manufacturing Value Added Impact.

The total output impact associated with the existence of an SMR related manufacturing facility would reach \$33.3 million annually. The facility itself would be responsible for \$25.2 million in economic activity and would stimulate \$3.8 million in output from suppliers and \$4.3 million from household expenditures.

Figure A-7. SMR Manufacturing Total Output Impact.

A-4.6 Community Wellbeing

Community wellbeing is not estimated as part of the IMPLAN model. However, there are likely to be impacts to public services and quality of life that should be explored if a community wishes to build a manufacturing facility. If new workers move to the area there will be greater demands on housing, public resources, and services such as schools and emergency response, and a possibility for increased traffic

and noise among other impacts. Some of these may be offset by increased economic activity and reinvestment in infrastructure and services.

A-4.7 Equity and Environmental Justice

Equity and environmental justice aspects of a manufacturing facility should be carefully considered before moving forward with this opportunity. These may include investigating impacts of siting a facility on nearby neighborhoods and access to workforce development programs and jobs for local residents.

A-4.8 Infrastructure

A manufacturing facility will depend on infrastructure for operations and distribution. Proximity to existing resources and the possibility of developing new infrastructure will need to be evaluated as part of this opportunity.

A-4.9 Government Benefits

SMR manufacturing will support construction of new clean energy infrastructure by supplying inputs for small modular reactor construction. This supports Federal government missions. State and local government are likely to benefit from additional tax revenue generated. These benefits have not yet been quantified.