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A Capitals Approach to Biorefinery Siting Using an Integrative Model

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Introduction

Biorefinery site selection is critical to producing economically viable and environmentally sustainable biofuels. Facility siting requires significant financial investments and long-term strategic commitments. These decisions are primarily driven by economic factors, such as access to labor and markets, raw materials, and cost-reducing local incentives (Noon, Zhan, and Graham 2002). Economic criteria will always be central to site selection decisions. However, nontechnical considerations are also critical and can be among the largest obstacles to successful high-tech facility siting (Plate, Monroe, and Oxarart 2010; Rösch and Kaltschmitt 1999; White 2010).

Understanding local communities' influence on the outcomes of biorefinery siting is gaining traction, but it is difficult to measure and incorporate into the site selection process. In cases where bioenergy projects failed despite positive feasibility studies, Christine Rösch and Martin Kaltschmitt identified a number of issues: funding, financing, and insuring problems; unfavorable administrative conditions; organizational difficulties; limited

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knowledge and information; and lack of public acceptance (1999). Leann M. Tigges and Molly Noble found that securing community support can lower implementation costs (2012). Similarly, Arifa Sultana and Amit Kumar (2012) assumed that inclusion of strong socioenvironmental considerations in facility siting would enhance project social acceptability, and Miet Van Dael et al. (2012) used proxies to estimate support for a bioenergy project, including unemployment numbers, community acknowledgment of the Kyoto protocol, and unutilized industrial areas. However, community support is only one among several assets necessary to sustain biorefineries. The presence of social assets, in sufficient levels, can aid project development, implementation, and sustainability (Martinkus et al. 2017b; Rijkhoff et al. 2017). This presence is not only beneficial for siting from the developer's point of view, but the community benefits as well. Facility development can lead to increased job opportunities, tax revenues, and local infrastructure improvements (Cambero and Sowlati 2016). It is therefore critical to engage communities in the decision-making process, especially in controversial decisions such as energy development, to address potential public suspicion or distrust of the process. Collecting community input and involving community members in the decision process will do much to enhance project understanding and cooperation (Parks, Joireman, and Van Lange 2013). In this chapter, we discuss how decision support tools can enhance industry and public understanding, thus aiding site selection decisions.

Our interdisciplinary team has developed a decision support tool (DST) based on multicriteria decision analysis to aid high-tech facility siting decisions, including biorefineries (Martinkus et al. 2017b), where use of such tools is increasing (see Perimenis et al. 2011). The tool was developed with the Northwest Advanced Renewables Alliance (NARA), a group examining aviation biofuels and co-products supply chains using postharvest forest residues (e.g., slash).[1] Although the DST was developed for, and is applied to, siting biorefineries in the Pacific Northwest (PNW) region of the United States, the nationwide, county-level datasets used in the tool make it flexible enough to explore site selection options for a wide range of high-tech industries.

Our DST combines traditional economic siting criteria with underutilized social assets, particularly critical for renewable energy projects such as forest biorefineries (Cambero and Sowlati 2014). The social assets dataset, developed by Rijkhoff et al., includes social, cultural, and human capitals (2017).

Our multicriteria DST converts disparate qualitative and quantitative data into a consistent quantitative dataset to identify suitable biorefinery sites through weighting economic, physical, and social criteria by importance (Wang et al. 2009). The multicriteria DST is not meant to identify the right site, but narrow a large list of potential facilities or sites to a few top candidates for further investigation.

The development and implementation of the DST contribute to the discussion of how social and technical issues related to energy production interact. Our approach goes beyond the dimensions of technology and economics to include essential social and human elements. Our innovative DST involves quantitative indicators for economic and social criteria that can be used to assess facility siting options both regionally and nationally. Traditionally, inclusion of social assets in decision-making processes is obtainable only using costly research methods. As such, our DST provides a powerful tool for initial assessment for industry and policy makers. It can be applied to energy or other siting issues, adding a more holistic understanding of communities to meet their shared goals.

The objectives of this chapter are to (1) describe the economic and social criteria used in the multicriteria biorefinery siting DST; (2) validate the social asset dataset with case study analyses of four high-tech facility siting cases; and (3) demonstrate how the DST uses nationally available, county-level data to develop a rough ranking of, in our example, forest biorefinery facility siting options. We conclude the chapter with insights and recommendations for siting decisions based on multicriteria decision making, aided by DSTs.

Methods

The development of the DST represents an interdisciplinary effort, utilizing a sequential mixed-method integrated design to inform site selection decision-making processes. In this section, we briefly describe the methodology used in developing and validating components of the multicriteria DST.

Community Capitals Framework

We use the Community Capitals Framework (CCF) to guide the development of the siting criteria and indicators. This systems framework identifies

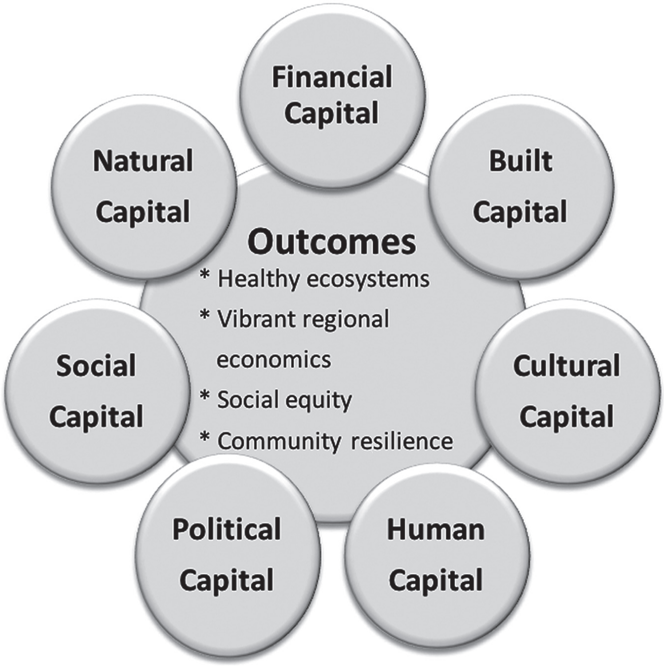

FIGURE 7.1. Community capitals framework. Source: Rijkhoff et al. 2017, based on Emery and Flora 2006, 21.

community assets as seven capitals: natural, built, social, cultural, human, financial, and political (figure 7.1) (Emery and Flora 2006). The CCF allows us to analyze community suitability more holistically for site selection. Six of the seven capitals are included in the DST; the exception is political capital, which is undeniably important but requires a more in-depth, site-specific analysis.[2]

To incorporate the CCF in the DST, two teams of researchers—representing economic, geospatial, political, and social sciences—conducted extensive literature reviews of multiple disciplines to identify potential quantitative indicators reflecting each capital. The teams also researched publicly and privately held secondary datasets that are available for all of the United States and at the county level, a sufficient scale to allow for regional comparison. After identifying indicators and datasets, the research teams created measures used in the DST. We describe the criteria and indicator development in "Developing the Indicators and Measures."

Case Studies of Social Assets

While extensive research and applications are available for quantitative indicators of natural, built, and financial capital in site selection, quantitative indicators of social assets are still relatively developmental and incomplete in site selection research. Further research is required to validate the social asset indicators and identify opportunities to improve the initial methodology for future DSTs. To examine social assets, we conducted case studies in four communities where high-tech biomaterial facilities were proposed or constructed through twenty-one semistructured phone interviews with stakeholders between January and March 2017. Participants were identified through purposive and snowball sampling methods to include a range of perspectives. They represent key actors involved in the facility implementation process, with knowledge beyond the general population.

Interview data were supplemented with secondary sources, including local newspaper articles, public meeting minutes, public outreach and information meeting videos, feedstock analysis plans, policy documents, and local internet sources for community history and background. All interview transcripts were coded thematically to ensure consistency throughout the cases. Two independent researchers coded a sample of the findings to ensure intercoder reliability. There was substantial agreement between raters, $K = 0.68$ ($p < .001$), 95% CI (0.52609, 0.82792).

DST and Application

The DST translates the CCF indicators into biorefinery siting criteria. Each criterion is assigned a weight and range of scale values. Weights define the relative importance of each criterion, and scale values provide a means for assessing existing facilities based on location-specific values relative to the range of values present. A higher scale value means a facility's location-specific value provides a lesser cost to operate the biorefinery than the other facilities. Each facility receives a score based on how well its assets provide for reduced costs; we favor repurposing existing facilities over greenfield development as a means to reduce capital expenditures (Martinkus and Wolcott 2017). The highest scoring facility would theoretically cost the least to repurpose and operate as a forest biorefinery. Both economic and social criteria are included in the DST as separate modules with separate weights; however,

TABLE 7.1. Decision support tool framework

	Economic Metric			*Social Metric*	
	Criterion 1 (C1)	*Criterion 2 (C2)*	*Criterion n (Cn)*	*Criterion 1 (C1)*	*Criterion n (Cn)*
Scale, *s*					
5	*amax*	*bmin*	*cmin*	*amax*	*bmin*
4	*amax − B1*	*bmin + B2*	*cmin + Bn*	*amax − B1*	*bmin + Bn*
3	*amax − 2B1*	*bmin + 2B2*	*cmin + 2Bn*	*amax − 2B1*	*bmin + 2Bn*
2	*amax − 3B1*	*bmin + 3B2*	*cmin + 3Bn*	*amax − 3B1*	*bmin + 3Bn*
1	*amax − 4B1*	*bmin + 4B2*	*cmin + 4Bn*	*amax − 4B1*	*bmin + 4Bn*
Weight	*w1*	*w2*	*wn*	*w1*	*wn*

the scores from each are combined to create one final facility score. Table 7.1 illustrates the general form of the DST.

We apply the DST to locating a forest biorefinery in the PNW. The region is well suited to hosting such a facility, with existing physical infrastructure and ample biomass to meet the annual feedstock requirement. Ten active or recently decommissioned pulp mills are assessed for their repurpose potential as a forest biorefinery.

Developing the Indicators and Measures

DST development utilized mixed methods and two research teams to develop the tool's criteria guided by the CCF. The economic and geospatial team led identification of natural, built, and financial capitals, while the social asset team focused on measures for social, cultural, and human capital. Table 7.2 shows the multicriteria dataset used in the DST (Martinkus et al. 2017b).

Economic Criteria Development

Economic site selection criteria are identified from a biorefinery's technoeconomic analysis (TEA). The TEA delineates capital and operating costs for all processing units within the biorefinery and determines the minimum fuel selling price. Some cost components vary geospatially based on facility location (e.g., electricity rates, feedstock cost). By using these economic costs as siting criteria, we can identify sites that may operate at the least cost.

TABLE 7.2. Overview of indicators used in the decision support tool (DST)

Assets	*Community Capitals*	*Indicators*
Economic and Physical Criteria	*Natural capital* Source: Martinkus et al. (2017a)	Annual biomass availability
	Built capital Source: Esri (2017); Martinkus and Wolcott (2017)	Multimodal transportation (as part of biomass availability) Facility repurpose potential
	Financial capital Source: US Energy Information Administration (2014a)	Electricity / natural gas rate Labor costs (wages)
Social Assets	*Social capital* Source: Rupasingha, Goetz, and Freshwater (2006) (2009 data)	# Rent-seeking groups: political, labor, professional, and business organizations # Non-rent–Seeking Groups: civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations # Nonprofit organizations % Voter turnout
	Cultural capital Source: WESTAF (2010)	# Arts-related organizations # Arts-related business # Occupational employment in the arts $ Revenues of arts-related goods and services
	Human capital Source: County Health Rankings (The Robert Wood Johnson Foundation 2013)	Health: % Low birthrate % Premature deaths % Obese (BMI > 30) % Self-reports of poor health condition (physically and mentally)

Note: All counts (#) and amounts ($) are calculated as a rate of the population per 10,000.

NATURAL CAPITAL

Natural capital is represented by the amount of feedstock available to a facility at a given cost. In our case, we assess the availability of postharvest forest residue as the feedstock for a forest biorefinery producing aviation biofuel. Forest residue volumes available at discrete locations throughout the PNW are determined as twenty-year averages (Martinkus et al. 2017a).

BUILT CAPITAL

Built capital is reflected in both the road transportation system and the existing facility infrastructure assessed for its repurpose potential. The forest residue volumes are routed along road networks utilizing least-cost routing algorithms to determine the least cost path between each biomass source point and industrial facility. The sum of all transportation costs are aggregated over all source points until annual biorefinery demand is met (Martinkus et al. 2017a). The total weighted average delivered feedstock cost to meet annual biorefinery demand is determined for each existing industrial facility and is used as a siting criterion.

The capital cost to construct a biorefinery may be reduced if existing facility infrastructure and assets can be repurposed. Existing facilities are assessed against the requirements of a greenfield biorefinery for their infrastructure compatibility to estimate the capital percent savings realized through repurposing (e.g., Martinkus and Wolcott 2017). This criterion prioritizes existing facilities that would theoretically cost the least to repurpose (Chambost, Mcnutt, and Stuart 2008).

FINANCIAL CAPITAL

Financial capital is examined here as the costs associated with biorefinery operation that vary geospatially, including energy and labor costs. Electricity and natural gas criteria are developed by aggregating energy data to the county level and averaging over the years 2010–2014 (US Energy Information Administration 2014a, 2014b). The labor criterion is developed through averaging weekly labor rates at the county level over the years 2012–2014 (US Bureau of Labor Statistics 2015).

Economic Criteria Weight Development

The economic criteria weights are developed using the biorefinery's TEA. Regional average energy rates and weighted average feedstock cost are inputted into the TEA, and regional average *annual* costs for the siting criteria are determined. The region examined is all counties in which candidate facilities reside. The repurpose potential criterion "cost" is developed by converting the total capital expenditure for constructing a greenfield biorefinery into an annualized expense, assuming a plant life (*n* years) and discount rate *r* using the Capital Recovery Equation. The average annual costs are summed, and the percentage of each criteria cost, out of total average cost, is determined. These percentages are the basis for the criteria weights. The percentages are normalized based on the range of scale values in the DST so facility scores can be calculated out of a total score of 100 for ease of understanding the results.

Social Asset Criteria Development

The DST's social asset criteria were developed by Rijkhoff et al. (2017) to give initial insights into nontechnical siting considerations. The social asset dataset provides quantitative proxy measures for social, cultural, and human capital (Martinkus et al. 2017b; Rijkhoff et al. 2017). Social asset quantification is difficult since each consists of multiple, often qualitative, indicators. However, while limited, the measures provide essential data for initial evaluation of candidate communities.

SOCIAL CAPITAL

Social capital reflects community connections, both among people and through organizations. It positively influences economic growth, promotes trust, and increases collective action through social networks that aid cooperation (Coleman 1988; Montgomery 2000; Putnam 2000; Rupasingha, Goetz, and Freshwater 2006). Quantitative indicators often used to measure social capital include the number of *rent-seeking* and *non-rent–seeking groups*,[3] nonprofit organizations in a community, and voter turnout. These indicators are incomplete representations of social capital; however, they are good proxies for measuring community-level social capital (Putnam 2000; Rupasingha, Goetz, and Freshwater 2006). The DST's social capital score was developed with the following indicators: all community organizations, nonprofit organizations, and voter turnout (Rijkhoff et al. 2017).

Cultural Capital

Cultural capital, also sometimes called creative capital, refers to community traditions and languages, people's perceptions of and interaction with the world around them, and acceptance of creativity and innovation (Emery and Flora 2006). Creativity is important for project success (Budd et al. 2008; Martinkus et al. 2014; and Martinkus et al. 2017b). Florida developed a comprehensive measurement of the creative using four indicators: the creative class (people with jobs that require creativity), innovation, high-tech industry, and diversity. Together, all weighted equally, these indicators form the Creative Vitality Index (CVI) (Florida 2002). Our cultural capital measure includes the number of arts-related organizations and businesses, the number of people employed in these organizations and businesses, and the revenues of arts-related goods and services (Rijkhoff et al. 2017).

Human Capital

Human capital addresses people's skills and abilities, which helps with assessing local workforce quality. Human capital is important to equitable and sustainable development solutions (Pretty and Ward 2001). The original social asset dataset used the following human capital indicators: community health, poverty levels, unemployment rate, and education levels (Rijkhoff et al. 2017). For the current DST, we utilized the community health indicators only to avoid potential overlap between the economic and social asset indicators.

Social Asset Scores

For the three social asset capitals, Rijkhoff et al. (2017) calculated a single capital score for each county, reflecting its performance for that capital. For social and human capital, individual indicators were multiplied by their factor loadings to create a single capital score. Since CVI is a nationwide index, the adapted CVI score for each county was utilized. Rijkhoff et al. (2017) used the US Census Region West to develop cutoff scores for each capital based on average regional performance. A county over the cutoff outperforms regionally and thus may be a stronger candidate for facility siting than those with scores below the cutoff value. Table 7.3 shows the cutoff scores for the Census Region West compared to those at the National level from Martinkus et al. (2017b).

The strength of the social assets dataset in the DST is the ability to narrow potential candidate sites by incorporating social criteria that are often

TABLE 7.3. Social, cultural, and human capital cutoff scores used in the decision support tool (DST)

Cutoff Scores		
	Census Region West	*National*
Social Capital	.0413	−.0043
Cultural Capital	.686	.491
Human Capital	−1.4247	.0838

Note: Asset ranges are provided in table 7A.1 of the appendix.

limited in siting decision frameworks. In fact, Rijkhoff et al. (2017) found in analysis of community-level projects that the social asset criteria were associated with project outcomes; cases above the cutoffs had positive results, while cases below had negative results. Social asset criteria inclusion does not replace the need for community engagement to ensure project success. Communities with high social capital can engage their networks to oppose a project; therefore, assessing community support and communicating with key actors are necessary before making final siting decisions.

Despite its benefits, the social asset criteria have limitations. To ensure national comparability, Rijkhoff et al. (2017) focused on obtaining county-level quantitative indicators, resulting in the exclusion of potential indicators that are unavailable at this level (e.g., trust). Additionally, robust indicators are unavailable at a lower level, such as city or town, which limits full consideration of sites in specific communities. Last, the social asset database does not include political capital; however, this indicator is currently being addressed for future inclusion.

To address these limitations, we conducted case studies to validate current indicators. These case studies examine the role of social, human, and cultural capital in the success or failure of community-level projects. The cases also assess indicators absent from the social asset dataset and suggest additional metrics for future DST iterations.

Ground-Truthing Case Studies

To assess the impacts of social assets in siting decisions, we selected four communities in the PNW where a high-tech biomaterial industry was proposed or constructed: Missoula, Montana; Lakeview, Oregon; Boardman, Oregon; and Tacoma, Washington. Stakeholder interviews explore the role of social, cultural, and human capital in facility development and implementation. Case study findings are compared to Rijkhoff et al.'s (2017) initial social asset measures to validate and refine future measures and to explore their impact in project implementation. The case and stakeholder characteristics are listed in tables 7.4 and 7.5.

Conceptualizing Success Each case was examined for its level of success or failure based on a protocol adapted from a retrospective analysis of past complex policy projects (Rijkhoff et al. 2017).

SUCCESS

Smooth operation throughout its existence: encountered little to no community resistance; encountered no significant legal roadblocks; stayed economically viable throughout its operation.

PARTIAL SUCCESS

Currently operating and producing fuel or biomaterials, or successfully moving through the public permitting process with local support: may have encountered legal or economic roadblocks (e.g., major environmental lawsuits or violations, or economic viability struggles); operates normally today and can remain economically viable.

PARTIAL FAILURE

Currently operating but forced to diversify operations for economic viability, compromising original purpose: lawsuits or environmental violations have impeded ability to operate continuously; financial problems have forced only periodic operation, limiting production.

FAILURE

Never built: encountered local opposition or severe economic constraints; operations shutdown completely due to local resistance, environmental litigation, or economic ruin.

TABLE 7.4. Overview of case study communities

City	*County*	*State*	*Incoming Facility*	*Feedstock Source*	*Product*	*Status*	*Rating*
Missoula	Missoula	Montana	Blue Marble Biomaterials	Agriculture and Forest Biomass	Biochemical	Operating	Success
Lakeview	Lake	Oregon	Red Rock Biofuels	Forest Biomass	Aviation Jet Fuel	Not yet built	Partial success
Boardman	Morrow	Oregon	ZeaChem, Inc.	Agriculture and Forest Biomass	Ethyl Acetate/ Ethanol	Operating	Partial failure
Tacoma	Pierce	Washington	Northwest Innovation Works	Liquid Natural Gas	Methanol	Never built	Failure

TABLE 7.5. Interview participants

Case	*Stakeholder Type*	*# Interviewees*
Missoula, MT	Nonprofit (1); government employee (1); university (1); private sector (1).	4
Lakeview, OR	Nonprofit (2); local/state government official (3); incoming facility (1).	6
Boardman, OR	Government employee (1); incoming facility (1); university (1); Local industry/private sector (2).	5
Tacoma, WA	Nonprofit (1); Local/state government official (1); government employee (2); university (1); local citizen (1).	6
	Total	21

Analysis

To assess the quantitative social asset indicators, a thematic analysis based on key literatures was performed; results were then compared to Rijkhoff et al.'s (2017) original county scores. Table 7.6 shows the conceptual coding framework used for interview analysis to examine the role of social, cultural, and human capital in facility siting decisions.

Missoula, Montana—Success

Blue Marble Biomaterials, operating since 2012, manufactures specialty chemicals from cellulosic biomass for food flavoring, fragrances, and cosmetics. It has been operating smoothly without community resistance. Key to its success are Missoula-based entrepreneurial and economic development organizations that help start-ups access grants, connect with stakeholders, and identify site locations. This formal infrastructure was important in relocating the facility from Seattle, Washington, where there was less stakeholder and economic support.

Rijkhoff et al. (2017) found favorable levels of social, cultural, and human capital for Missoula County (table 7.7). These scores are supported by interview data, which found the presence of several concepts of social capital, including bridging social capital and communication (table 7.7). Bridging social capital was particularly apparent, with a number of organizations and networks assisting start-ups and entrepreneurial ventures through the implementation process.

Cultural capital concepts focused on shared community values and sense of place. For example, Blue Marble uses cellulosic material from forest and agricultural waste to create biochemicals that replace their petroleum counterparts found in foods, fragrances, and other consumables. Stakeholders claimed the facility was seen as a "green" and "clean" industry and was readily accepted by the community.

Missoula stakeholders addressed availability of a skilled and educated workforce, components of human capital. All participants emphasized the University of Montana's role in connecting the company with a skilled workforce: "Having access to the University of Montana played a pretty key role for them. Whether it be recruiting students or doing research with a faculty, and that's been a big part of their reason for locating there" (interview with local nonprofit, February 2017).

TABLE 7.6. Interview coding themes

	Key Concept	*Descriptions*
Social Capital	Trust Bridging Bonding	Reflects the strength of connections among people and organizations within the community to make things happen (Emery and Flora 2006; Flora and Flora 2013). Social capital is often classified as either bonding social capital (ties that link individuals or groups with similar backgrounds) or as bridging social capital (connecting diverse groups within the community to each other and groups outside the community) (Emery and Flora 2006; Flora and Flora 2013; Putnam, Feldstein, and Cohen 2003).
	Modes of communication	Contact within, between, and across stakeholders and groups (Inkeles 2000).
Cultural Capital	Values History Legacy (industrial, environmental, social)	Consists of symbols and language and determines a community's distinctive character (Jacobs 2011). Cultural capital reflects the way people see the world and how they act within it, as well as their history, traditions, and language (Emery and Flora 2006; Flora and Flora 2013). Legacy is that which communities seek to pass on to the next generation.
	Sense of place	Describes our relationship with places, expressed in different dimensions of human life: emotions, biographies, imagination, stories, and personal experiences (Feld and Basso 1996).
Human Capital	Labor and workforce	Health of the potential workforces and ability of the community to be resourceful and access outside resources and bodies of knowledge (Emery and Flora 2006). The local labor force affects the community's success in attracting or supporting new business enterprises (Flora and Flora 2013).
	Skills (technical and intrapersonal) Knowledge (formal and informal) Experience	The ability of people based on their characteristics—such as formal and informal knowledge, technical and intrapersonal skills, experience, leadership, and talent—to develop and enhance their resources (Emery and Flora 2006; Gutierrez-Montes 2005).
	Capacity	Ability to access outside resources to contribute to local community and economic development (Emery and Flora 2006; Flora and Flora 2013).

Lakeview, Oregon—Partial Success

Red Rock Biofuels is the second biomass-related project to attempt to site in Lakeview, Oregon. The first, Iberdrola Renewables, failed because it could not obtain a power purchasing agreement from the local utility. However, this unsuccessful attempt demonstrated project feasibility, access to feedstock, physical infrastructure, and community support that appealed to Red

TABLE 7.7. Missoula, Montana: Interview findings compared to quantitative indicators

Assets	*Quantitative Social Indicators*		*Quantitative Levels*			*Qualitative Social Indicators*	*Present*[a]
Social Capital	Source: Rupasingha, Goetz, and Freshwater (2006) (2009 data)	# Rent-seeking groups: political, labor, professional and business organizations	Social Cap. 1997	Social Cap. 2005	Social Cap. 2009	Trust	—
		# Non-rent–seeking groups: civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations	1.20	2.07	1.84	Bridging	√
		# Nonprofit organizations				Bonding	—
		% Voter turnout				Modes of communication	√
Cultural Capital	Source: WESTAF (2010)	# Arts-related organizations	CVI 2008	CVI 2009	CVI 2010	Values	√
		# Arts-related business	.921	.956	.946	History	√
		# Occupational employment in the arts				Legacy	√
		$ Revenues of arts-related goods and services				Sense of place	√
Human Capital	Source: County Health Rankings (The Robert Wood Johnson Foundation 2013)	% Low birth-weight	Health 2013		2.38	Labor and workforce	√
		% Premature deaths	Obesity 2013		−5.30	Skills	√
		% Obese (BMI > 30)	Poverty 2013		−.95	Knowledge	√
		% Self-reports of poor health condition (physically and mentally)	Education 2013		16.00	Experience	√
			Language 2013		−2.90	Capacity	—

Note: Shaded cells indicate scores that are better than the cutoff scores and, thus, levels that are more likely to be favorable for positive project implementation. Cutoff scores are based on averages for the respective years and variables for the region West (US census region) of over 446 counties and divided by themselves so that all scores are comparable (Rijkhoff et al. 2017). Due to missing data in the health scale for some of the counties, raw obesity scores were added as comparison (Rijkhoff et al. 2017).

[a] A positive qualitative social indicator is noted with a (√); if the indicator was not present during the interview process then (—).

Rock Biofuels. While this facility has not yet been built, the company has attained several approvals for an enterprise zone, pipeline capacity, an urban growth boundary amendment, and air quality permits. It is labeled a partial success, largely due to the substantial community support for the project.

Rijkhoff et al. (2017) found favorable levels of social capital and mixed levels of cultural and human capital for this case (table 7.8). Interview data corroborate the high levels of social capital but indicate some social assets played less of a role. For instance, social capital concepts—including trust, bridging, bonding, and communication—were present in every interview (table 7.8). Lake County has established trust and working relationships between stakeholders through the Lakeview Stewardship Group; they have worked together on contentious forest management issues for over a decade. Some environmental advocates are unsupportive of an industry focused on small-diameter wood utilization due to fear of environmental degradation. However, the executive director of a participating nonprofit believes that these groups are not opposing the project, because of significant levels of established trust: "I think what we've got is a lot of trust over the years that we've built with the collaborative here and to have those honest discussions without threats and those kinds of stuff, is doable" (interview with local nonprofit, January 2017). The project, moving forward without opposition, is actively supported by local leaders who engage their networks to increase project viability by hosting conference calls to keep multiple stakeholders informed.

Cultural capital themes in Lakeview reflect local history, legacy, and community values. Stakeholders indicated that the project fits with the community's goals of creating a new economy based on natural resource and renewable energy development. They also have a social legacy that is more supportive of biomass projects than neighboring counties.

Absent in the interviews was a discussion of the local workforce. Only one stakeholder mentioned that implementing projects of this size could present challenges for rural communities. Project-related skills, technical knowledge, and local stakeholder experience are contributing to Lakeview's ability to support Red Rock through the implementation process.

The qualitative findings support the quantitative indicators, which showed favorable levels of social capital in Lakeview. The quantitative metrics did not indicate favorable levels of cultural capital, with the exception of 2009, and human capital measures are mixed, with underperforming education

TABLE 7.8. Lakeview, Oregon: Interview findings compared to quantitative indicators

Assets	*Quantitative Social Indicators*		*Quantitative Levels*			*Qualitative Social Indicators*	*Present*[a]
Social Capital	Source: Rupasingha, Goetz, and Freshwater (2006) (2009 data)	# Rent-seeking groups: political, labor, professional, and business organizations	Social Cap. 1997	Social Cap. 2005	Social Cap. 2009	Trust	√
		# Non-rent–seeking groups: civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations	3.00	2.64	2.81	Bridging	√
						Bonding	—
		# Nonprofit organizations				Modes of communication	√
		% Voter turnout					
Cultural Capital	Source: WESTAF (2010)	# Arts-related organizations	CVI 2008	CVI 2009	CVI 2010	Values	—
		# Arts-related business				History	√
		# Occupational employment in the arts	−.179	−.20	−.3171	Legacy	√
		$ Revenues of arts-related goods and services				Sense of place	—
Human Capital	Source: County Health Rankings (The Robert Wood Foundation 2013)	% Low birth-weight	Health 2013		−1.98	Labor and workforce	—
		% Premature deaths	Obesity 2013		−1.60	Skills	√
		% Obese (BMI > 30)	Poverty 2013		.87	Knowledge	√
		% Self-reports of poor health Condition (physically and mentally)	Education 2013		−1.00	Experience	√
			Language 2013		−4.00	Capacity	—

Note: Shaded cells indicate scores that are better than the cutoff scores, and thus, levels that are more likely to be favorable for positive project implementation. Cutoff scores are based on averages for the respective years and variables for the region West (US census region) of over 446 counties and divided by themselves so that all scores are comparable (Rijkhoff et al. 2017). Due to missing data in the health scale for some of the counties, raw obesity scores were added as comparison (Rijkhoff et al. 2017).

[a] A positive qualitative social indicator is noted with a (√); if the indicator was not present during the interview process then (—).

levels. However, cultural and human capital themes identified in stakeholder interviews suggest the presence of values, legacy, skills, and local experience that support the implementation process of the biofuel refinery (table 7.8).

Boardman, Oregon—Partial Failure

ZeaChem, Inc., is an ethanol and biochemical refinery located in the Port of Morrow's industrial park outside Boardman, Oregon. In 2012, ZeaChem completed construction of its demonstration biorefinery. Citing financial and technical challenges, ZeaChem has not reached commercial scale and is operating at limited capacity. Other setbacks include the loss of its primary feedstock source. ZeaChem is considered a partial failure because of its inability to scale up.

Rijkhoff et al. (2017) found mixed levels of human capital, and low levels of social and cultural (table 7.9) capital, which are partially supported in this case. The main social capital concepts were bonding, bridging, and communication. ZeaChem was said to be proactive with its communication and outreach efforts. Evidence of bonding social capital was present when a stakeholder described the community as insulated from outside influences (Roemer 2017). Early on, the company hired a local entrepreneur to coordinate communication between the company, community stakeholders, and outside networks and organizations. This early outreach contributed to building the refinery. However, this early engagement and support could not counter the technical and financial challenges that have kept ZeaChem operating at limited capacity.

The community's legacy and values stood out for cultural capital. The community is supportive of most economic development projects and especially projects that relate to food, agricultural, and timber industries. Stakeholders saw the project as a natural fit and easily supported the project. "We're an agricultural based economy, and so those industrial opportunities [are] value-added opportunities" (interview with local government employee, February 2017). They also said the project aligned with community values to have a "green industry." Boardman's industrial legacy and community values contributed to project acceptance and support.

Key human capital themes present were labor and workforce, skills, knowledge, and capacity. Participants cited challenges of getting technical experts from Denver, Colorado, and San Francisco, California, to relocate.

TABLE 7.9. Boardman, Oregon: Interview findings compared to quantitative indicators

Assets	*Quantitative Social Indicators*		*Quantitative Levels*			*Qualitative Social Indicators*	*Present*[a]
Social Capital	Source: Rupasingha, Goetz, and Freshwater (2006) (2009 data)	# Rent-seeking groups: political, labor, professional, and business organizations	Social Cap. 1997	Social Cap. 2005	Social Cap. 2009	Trust	—
		# Non-rent–seeking groups: civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations				Bridging	√
			.05	−.28	−.02	Bonding	√
		# Nonprofit organizations				Modes of communication	√
		% Voter turnout					
Cultural Capital	Source: WESTAF (2010)	# Arts-related organizations	CVI 2008	CVI 2009	CVI 2010	Values	√
		# Arts-related business				History	—
		# Occupational employment in the arts	−.55	−.59	−.55	Legacy	√
		$ Revenues of arts-related goods and services				Sense of place	—
Human Capital	Source: County Health Rankings (The Robert Wood Foundation 2013)	% Low birth-weight	Health 2013		−.92	Labor and workforce	√
		% Premature deaths	Obesity 2013		−1.00	Skills	√
		% Obese (BMI > 30)	Poverty 2013		.67	Knowledge	√
		% Self-reports of poor health condition (physically and mentally)	Education 2013		23.60	Experience	√
			Language 2013		4.40	Capacity	√

Note: Shaded cells indicate scores that are better than the cutoff scores and, thus, levels that are more likely to be favorable for positive project implementation. Cutoff scores are based on averages for the respective years and variables for the region West (US census region) of over 446 counties and divided by themselves so that all scores are comparable (Rijkhoff et al. 2017). Due to missing data in the health scale for some of the counties, raw obesity scores were added as comparison (Rijkhoff et al. 2017).

[a] A positive qualitative social indicator is noted with a (√); if the indicator was not present during the interview process then (—).

Stakeholders contended that when the project reached commercial scale, Boardman and the surrounding area could meet its labor and workforce needs. However, ZeaChem remains operating at the demonstration level. A ZeaChem representative stated that in addition to technical challenges, coordinating technical experts' schedules to work at the demonstration site likely contributed to financial and technological delays. This opinion is supported by initial social asset metrics, as Rijkhoff et al. (2017) predicted education levels below the regional average.

The qualitative data demonstrate concepts of social and cultural capital; however, the quantitative indicators show unfavorable levels of social and cultural capital, with both underperforming compared to the regional average.

Tacoma, Washington—Failure

The port of Tacoma was the proposed location of the Northwest Innovation Works (NWIW) natural gas–to–methanol production plant. The facility would export methanol to produce olefins for use in plastics and other goods. Despite early political support from Washington's governor and other public officials, the plant faced strong local resistance. The company terminated the facility lease before the environmental review was conducted.

Rijkhoff et al. (2017) did not find favorable levels of social, cultural, or human capital with the exception of education (table 7.10). The analysis of social capital in Tacoma demonstrated negative indicators of social capital. Communication failure and breakdowns between stakeholder groups eroded public support. All interviewees indicated that NWIW failed to address the community's environmental and safety concerns. Additionally, the port notified the surrounding communities and others about meetings through traditional modes of outreach (e.g., press releases, newspaper articles, etc.); however, this information did not reach community members, who learned about the incoming facility through social media. Feeling inadequately informed and distrustful, people began organizing in opposition to the facility. Several participants noted this swell of public participation was unusual and the result of high levels of public distrust.

Key concepts of cultural capital were found to influence the opposition to the incoming methanol refinery in Tacoma. Perceived negative industrial, environmental, and social legacies led some community members to voice

TABLE 7.10. Tacoma, Washington: Interview findings compared to quantitative indicators

Assets	*Quantitative Social Indicators*		*Quantitative Levels*			*Qualitative Social Indicators*	*Present*[a]
Social Capital	Source: Rupasingha, Goetz, and Freshwater (2006) (2009 data)	# Rent-seeking groups: political, labor, professional, and business organizations	Social Cap. 1997	Social Cap. 2005	Social Cap. 2009	Trust	X
		# Non-rent–seeking groups: civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations	−.90	−.70	−.75	Bridging	√
		# Nonprofit organizations				Bonding	—
		% Voter Turnout				Modes of communication	X
Cultural Capital	Source: WESTAF (2010)	# Arts-related organizations	CVI 2008	CVI 2009	CVI 2010	Values	X
		# Arts-related business				History	X
		# Occupational employment in the arts	−.76	−.06	−.36	Legacy	X
		$ Revenues of arts-related goods and services				Sense of place	X
Human Capital	Source: County Health Rankings (The Robert Wood Foundation 2013)	% Low birth-weight	Health 2013		.64	Labor and workforce	√
		% Premature deaths	Obesity 2013		3.80	Skills	—
		% Obese (BMI > 30)	Poverty 2013		−1.37	Knowledge	—
		% Self-reports of poor health condition (physically and mentally)	Education 2013		3.40	Experience	—
			Language 2013		−1.90	Capacity	—

Note: Shaded cells indicate scores that are better than the cutoff scores and, thus, levels that are more likely to be favorable for positive project implementation. Cutoff scores are based on averages for the respective years and variables for the region West (US census region) of over 446 counties and divided by themselves so that all scores are comparable (Rijkhoff et al. 2017). Due to missing data in the health scale for some of the counties, raw obesity scores were added as comparison (Rijkhoff et al. 2017).

[a] A positive qualitative social indicator is noted with a (√); if the indicator was not present during the interview process then (—); if the indicator was present in a negative manner, then (X).

concerns about environmental degradation and excessive water and energy consumption. Additionally, there was a social theme pervasive throughout the interviews that Tacoma gets Seattle's unwanted projects: "So, . . . while Tacoma apparently has become the petrochemical kitchen of the NW, Seattle gets the high-tech incubator jobs" (interview with local community member, February 2017).

The concepts of human capital focused primarily on the type and availability of the local workforce. When asked why they thought NWIW selected Tacoma, after first mentioning the natural and physical infrastructure, the interviewees described the workforce as ideal for this industry. This finding supports Rijkhoff et al.'s (2017) quantitative assessment indicating supportive levels of education in the county.

While this case demonstrates social organization forming against the project, influenced by negative industrial histories and legacies, neither the interview findings nor quantitative indicators (table 7.10) suggest favorable levels or themes of social, human, or cultural capital in support of this project implementation.

Case Study Conclusions

Data from the four cases show that social, cultural, and human capital can play a significant role in complex project siting decisions. In these cases, the social asset metrics are mostly supported by the interviews, lending support for their inclusion in our DST. However, the data also reveal both limitations of these measures and opportunities for improvement.

In the two cases of success/partial success, the quantitative indicators showing higher levels of social capital were supported by stakeholder interviews. Stakeholders noted the importance of bridging organizations in supporting projects through the implementation process, particularly well-connected nonprofit organizations. These groups facilitated communication between stakeholders and with other sectors of the community.

In addition, communication played a significant role in two ways: (1) how well and often multiple stakeholders communicated and (2) how well companies or public officials presented information to the public. In the successful case, stakeholders mentioned a major factor in Blue Marble's decision to relocate from Seattle to Missoula was the ease of access to, and communication with, vital local stakeholders. In contrast, NWIW's failure to address the local environmental and safety concerns in Tacoma contributed to strong opposition of the methanol refinery.

Previous work (Fey, Bregendahl, and Flora 2006; Klamer 2002) finds that cultural capital plays an important role in community economic development, including a community's capacity for creativity, innovation, and willingness to take risks and their shared legacy and values (Tigges and Noble 2012). The cultural capital measure used in the DST, the CVI, indicated favorable levels in the Missoula case, but case study analysis suggests these measures can be improved. For example, evidence of creativity, innovation, and risk taking was prominent in Lakeview. In both Lakeview and Boardman, the biofuel refineries were publicly supported because the projects aligned with a shared and valued legacy of timber and agricultural industries. In Tacoma, a legacy of environmental degradation, combined with NWIW's failure to address the community's fears, fueled opposition to the project. These aspects of cultural capital are not currently measured by the quantitative cultural capital indicator.

Whether the case study findings can validate human capital quantitative indicators is unclear. Both Tacoma and Missoula stated that the local workforce could support the incoming refinery. In Boardman, ZeaChem faced challenges coordinating outside experts' schedules for its demonstration facility, which stakeholders indicated impacted start-up and development. Lakeview stakeholders only mentioned the workforce in relation to having a small administrative staff, possibly indicating limited human capital.

There are limitations to the case studies. With only four communities, the size and scope of the assessments were restricted, and facilities examined were at different stages of development. For example, Lakeview is determined a partial success because, while the facility has not yet been built, the company has attained approvals for an enterprise zone, pipeline capacity, an urban growth boundary amendment, and air quality permits, and it is preparing for construction (Liedtke 2018). In contrast, ZeaChem is a partial failure because of financial and technical reasons, not insufficient social assets. As these cases are in various stages of development, future research is needed to determine if initial designations of success or failure still apply. However, at this time, the case studies indicate that the quantitative social asset indicators currently being used in the DST provide a more robust assessment for facility siting decisions compared to those that rely on traditional siting criteria (Martinkus et al. 2017b).

Decision Support Tool: Full Model

The DST's social asset inclusion creates a multicriteria tool that combines these assets with traditional economic site selection criteria (table 7.2). The current DST refines the social asset metrics of Rijkhoff et al. (2017) by adopting a scale measure of each capital rather than the cutoff scores, allowing for a more nuanced analysis of assets, especially for communities close to the cutoff.

As mentioned, each facility receives a score based on how well its assets compare to the siting criteria. Individual facility scores are calculated using the Weighted Sum Method (Wang et al. 2009), which represents the sum of individual criterion weights multiplied by location-specific scaled values and by an overall economic or social metric weight (equation 1).

$$F_j = \sum_{x=1}^{2} \theta_x \sum_{i=1}^{n} w_i \, s_{ji} \quad where \sum \theta_x = 1 \qquad Equation\ 1$$

where $\boldsymbol{F_j}$ is the score for facility $\boldsymbol{j}$, $\boldsymbol{w_i}$ is the weight for criterion $\boldsymbol{i}$, $\boldsymbol{S_{ji}}$ is the scaled value for criterion $\boldsymbol{i}$ at facility j, n is the total number of criteria, and theta x is the overall user-defined weight for metric x. Here, each metric is assigned a theta$x$ = 0.5, thus giving both metrics equal weight and importance. The overall weights can be adjusted (as long as they sum to 1) to provide greater importance to either the economic or social metric, thus potentially altering the final site selection.

Each criterion's range of facility-specific economic and social values is used to determine the range associated with each scale value. The criterion-based "bin" values ($\boldsymbol{Bi}$) are determined by dividing the range of facility values ($\boldsymbol{a_{i,max}}$, $\boldsymbol{a_{i,min}}$) by the maximum scale value ($\boldsymbol{smax}$) for each criterion i (equation 2, table 7.1).

$$B_i = \frac{a_{i,max} - a_{i,min}}{s_{max}} \qquad Equation\ 2$$

The maximum scale value is assigned to the minimum or maximum value in each criterion's range of values that denotes the most positive influence on facility siting, such as low electricity rate or high infrastructure compatibility. The subsequent scale values are calculated by either adding or subtracting $\boldsymbol{B_i}$ based on the positive or negative influence of the criterion (table 7.1).

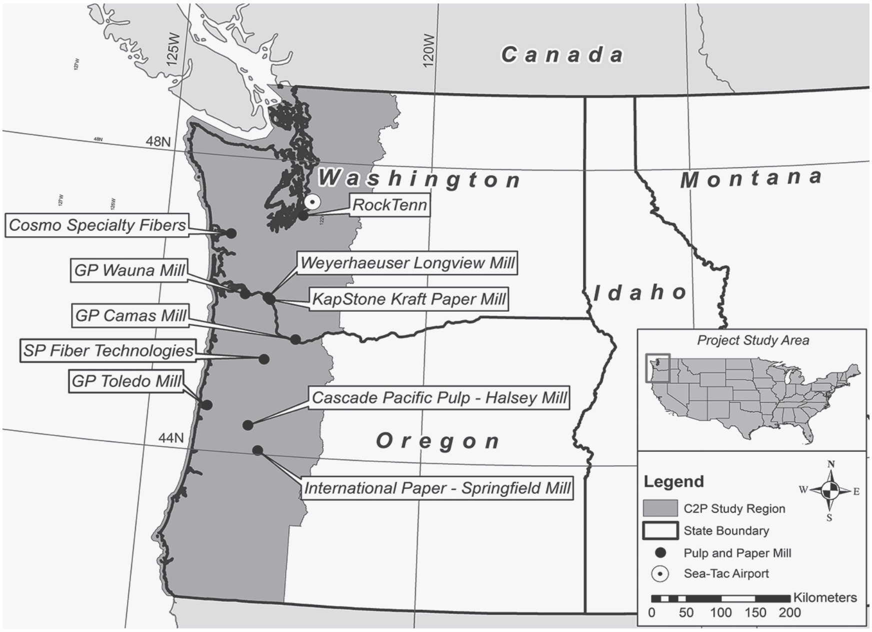

FIGURE 7.2. Cascade-to-Pacific (C2P) study region and candidate biorefinery sites.

Decision Support Tool Application

We applied the DST to locating a forest biorefinery in a region of the PNW we call the Cascade-to-Pacific (C2P), representing western Oregon and Washington (figure 7.2). Ten active or recently decommissioned pulp mills are assessed for their repurpose potential as a forest biorefinery serving the Seattle-Tacoma International Airport. This region has the existing physical infrastructure and ability to meet an annual feedstock requirement of about 830,000 bone-dry tons (BDT) of postharvest forest residues. Such a facility could produce approximately 36 million gallons of isoparaffinic kerosene (IPK), or aviation biofuel, from the feedstock through an enzymatic hydrolysis, fermentation, and catalytic conversion process (Zhu 2015). See table 7.11 for the decision matrix, and table 7.12 for the scaled values and overall facility scores.

Results

If the facilities are evaluated based on economic metrics alone (Economic Score column), Cosmo ranks highest due to infrastructure compatibility, low

TABLE 7.11. Decision matrix for C2P facility site assessment

	Economic Metric					*Social Metric*		
	Natural Capital	*Financial Capital*			*Built Capital*			
	Weighted Average Delivered Feed-stock Cost ($/BDT)	*Electricity ($/kWh)*	*Natural Gas ($/k.c.f.)*	*Average Wage ($/week)*	*Infrastructure: % Cost Reduction from Greenfield*	*Social Capital*	*Cultural Capital*	*Human Capital*
Scale								
5	62.7	0.047	7.5	571	40.6%	0.6	1.0	−2.9
4	65.3	0.051	7.9	627	39.2%	0.3	0.8	−2.0
3	67.8	0.055	8.3	683	37.8%	−0.4	0.7	−1.1
2	70.4	0.058	8.6	739	36.4%	−0.5	0.6	−0.2
1	72.9	0.062	9.0	795	34.9%	−0.9	0.4	0.8
weights	5.9	4.0	0.9	1.8	7.4	6.67	6.67	6.67

electricity rate, and relatively low costs for feedstock and fuel transport (table 7.12). These criteria are weighted the highest due to the large annual operational expenses they impose on the biorefinery. However, when considering the county's social assets, Cosmo ranks fourth due to low cultural and human capital (Social Score column). The low human capital score suggests that repurposing this pulp mill into a forest biorefinery may be hard due to workforce issues, suggesting the need to relocate labor or to provide ongoing training. In addition, the lower cultural capital scores could suggest a community with limited ability to adapt or creatively approach problems that might occur in the permitting process or other development stages.

When considering economic and social criteria equally, GP Wauna ranks highest (Facility Rank column). This facility has low infrastructure compatibility (the highest economic weight), yet it scores relatively high for all other economic metrics, and it ranks highest for all social metrics. To convert GP Wauna into a biorefinery, construction improvements may cost more, but the facility may also experience a faster permitting process due to the community's high social cohesion and potential ability to tackle difficult issues productively. This presumed capability translates into a faster start-up time, with construction costs recouped sooner, compared to a facility that may require less capital to repurpose but that encounters delays in permitting or due to public opposition.

TABLE 7.12. Scaled facility values and resulting scores C2P

	Economic Metric Weight, $\theta x = 0.5$							*Social Metric Weight, $\theta x = 0.5$*					*Final Facility Score and Rank*	
Facility	*Weighted Avg. Delivered Feedstock Cost ($/BDT)*	*Electricity ($/kWh)*	*Natural Gas ($/k.c.f.)*	*Avg. Wage ($/wk.)*	*% Cost Reduction from Greenfield*	*Economic Score*	*Weighted Score (Econ. Score x 0.5)*	*Social Capital*	*Cultural Capital*	*Human Capital*	*Social Score*	*Weighted Score (Social Score x 0.5)*	*Total Weighted Facility Score (= Wtd. Econ. Score + Wtd. Social Score)*	*Facility Rank*
Cascade Pacific	3	1	5	3	1	39.0	19.5	3	1	3	46.7	23.3	42.8	9
Cosmo	4	5	2	4	5	89.6	44.8	3	1	1	33.3	16.7	61.5	4
GP Camas	4	3	5	1	1	49.3	24.7	1	3	5	60.0	30.0	54.7	7
GP Wauna	4	4	5	4	1	58.7	29.4	5	5	5	100.0	50.0	79.4	1
GP Toledo	1	2	5	5	1	34.8	17.4	5	5	3	86.7	43.3	60.7	5
IP Springfield	3	2	5	3	1	43.0	21.5	3	5	4	80.0	40.0	61.5	3
Kapstone	5	5	2	1	1	60.5	30.3	2	1	1	26.7	13.3	43.6	8
RockTenn	4	1	1	1	1	37.7	18.9	1	3	3	46.7	23.3	42.2	10
SP Fiber	4	5	5	3	3	75.7	37.9	2	2	5	60.0	30.0	67.9	2
Weyerhaeuser	5	5	2	1	4	82.7	41.4	2	1	1	26.7	13.3	54.7	6

Note: Raw facility scores can be found in appendix table 7A.2.

As we have stated previously, the biorefinery siting DST is meant to refine a large list of potential facilities to a few top candidates for further investigation. Assessments are performed based on publicly available data, which enhances both its trust and transparency and which increases compatibility and comparability across the United States. Once a list of preferred candidate facilities is identified, in-depth community and facility analyses must be performed to identify the major concerns that would prevent or delay the facility's efficient repurposing.

Conclusion and Strategic Considerations

A multicriteria DST can be instrumental in effective facility siting due to its unique ability to combine multifaceted and divergent assets into a single framework for assessing candidate communities. The CCF provides a systematic framework for determining levels of community assets (or capitals) and the interaction between assets; however, the framework's qualitative nature limits its effectiveness for broad-based community comparison because of its data-rich needs. Our innovative, cross-disciplinary DST links the CCF to quantitative indicators to assess facility siting options both regionally and nationally. As such, this tool is powerful for initial assessment. Unfortunately, highly technical facility siting analysis are often conducted without critical social assets included, which limits the ability to predict successful implementation. Social assets not only provide assessment of the likelihood of community support, but they also address other critical aspects of project success that can aid project development, implementation, and sustainability. Our integrated DST was developed to identify forest biorefinery sites in the PNW, but it could be applied throughout the United States, for bioenergy or other industrial siting applications.

Case studies findings illustrate that the selected social asset indicators are effective proxies for assessing the presence of social, cultural, and human capital, despite using somewhat dated quantitative data (e.g., 2009, 2010, and 2013).[4] Although the case studies reveal the social asset indicators could be refined further, the current dataset is adequate for identifying host communities more likely to sustain a biorefinery. The case studies also indicate that the type of facility matters, particularly regarding whether it is a good fit with the community's culture. However, this is not a limitation of the DST because physical indicators, such as infrastructure and feedstock, would need to be adjusted to accommodate different types of facilities, and social assets are no different. Incorporating social assets into the DST does not eliminate the need for context-specific knowledge of candidate communities in order to enhance the likelihood of community acceptance of a siting decision. The tool does, however, provide an important initial assessment of these communities, resulting in a reduced number of sites to consider in greater detail.

The multicriteria DST has many strategic applications. High-tech facility siting is complex and often highly contentious. A critical role in the decision-making process for tools such as our DST is being a "boundary object" or a tool that can facilitate communication and learning between individuals and groups with disparate interests (McKnight and Zietsma 2007). Historically, DSTs have been used by industry leaders performing site selection to identify candidate locations that meet their needs and provide reduced capital and operational costs (Noon, Zahn, and Graham 2002). However, with growing interest in engaging stakeholders and the general public in environmental decisions, the DST can be extremely useful in creating a common understanding (Beierle 2002).

Our DST is also useful for economic developers to attract bioenergy, high-tech, or renewable energy developments to their region, especially given the growing interest in state- and local-level renewable energy production (Durkay 2017). The DST supports economically sustainable development by favoring existing facilities but is equally adept at assessing greenfield locations. With the incorporation of social assets, stakeholders can determine a community's readiness to accept a specific proposal and identify areas of limited social capacity. For instance, a community that underperforms in social capital may benefit from strategic engagement of economic developers to enhance citizen trust and support for particular industries (e.g., biorefineries or wind/solar farms). Lower levels of human capital may indicate a need to improve local workforce skills or bringing in key operational personnel. The DST analysis can indicate a communities' existing assets and highlight weaknesses to bolster or enhance the communities' appeal to industry investment.

While a DST can be a powerful tool for site selection, it is not without its weaknesses as the quality of the data used in the tool determines its accuracy. These tools require frequent updating, can be complex and difficult to understand, and require transparency about their uses and limitations. Weights should be evident and grounded in the literature. In our DST, we weighted the economic siting criteria using a quantitative assessment of the biorefinery TEA, while all social capitals were weighted equally. Performing sensitivity analyses, where weights and cost estimates are adjusted, can provide additional levels of understanding about the DST's outputs (Martinkus et al. 2017b). A DST also does not inform about risks involved in project development and implementation. Despite these limitations, the DST provides more information to industry, community leaders, and local stakeholders about candidate communities. This information can enhance the likelihood of implementation success through strategic engagement that reduces costs associated with community opposition, citizen distrust, and insufficient labor. The DST presented here can play an important role in high-level policy decisions and local permit approval. Moreover, DSTs can be crucial for nascent industries that must operate at reduced costs until market share can be achieved.

Appendix

TABLE 7A.1. Social, cultural, and human capital cutoff scores and ranges

Asset	*Indicators*		*Census Region West*	*National*
Social Capital		Average	.041	−.004
		Range	−3.06–7.88	−4.29–23.08
Creative Capital[a]		Average	.69	.49
Human Capital	Health	Average	−1.425	.084
		Range	−7.66–6.21	−7.66–12.50
	Obesity	Average	25.8%	30.3%
	Poverty	Average	.33	−.15
		Range	−5.65–7.82	−5.65–7.82
	Education	Average	58.0%	54.2%
	Language	Average	3.20%	1.80%

[a] For Creative Capital there is no range available due to the nature of the data. Please see Rijkhoff et al. (2017), for more details.

TABLE 7A.2. Original facility scores from decision support tool in the PNW

	Economic Metric					*Social Metric*		
	Natural Capital	*Financial Capital*			*Built Capital*			
Facility	*Weighted Average Delivered Feedstock Cost ($/BDT)*	*Electricity ($/kWh)*	*Natural Gas ($/k.c.f.)*	*Average Wage ($/week)*	*Infrastructure: % Cost Reduction from Greenfield*	*Social Capital*	*Cultural Capital*	*Human Capital*
Cascade Pacific	$68.59	.066	7.8	724	34%	−.46	.30	−.71
Cosmo	$65.51	.048	8.8	647	41%	−.30	.31	1.49
GP Camas	$67.60	.055	7.5	851	34%	−1.29	.60	−2.40
GP Wauna	$65.26	.053	7.8	629	34%	.64	.99	−2.61
GP Toledo	$75.44	.062	7.8	571	34%	.29	.90	−0.58
IP Springfield	$69.69	.062	7.8	712	34%	−.15	.96	−1.62
Kapstone	$62.97	.047	8.8	823	34%	−.66	.33	1.67
RockTenn	$67.35	.063	9.4	812	34%	−1.10	.66	−.91
SP Fiber	$66.49	.049	7.8	688	38%	−0.68	.51	−2.88
Weyerhaeuser	$62.71	.047	8.8	823	39%	−.66	.33	1.67

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Notes

1. NARA, funded by the US Department of Agriculture's National Institute of Food and Agriculture (NIFA), facilitates the development of sustainable biojet fuel, high-value co-products made from lignin, supply chain coalitions, rural economic development, and bioenergy literacy in Washington, Oregon, Idaho, and Montana. For more information, see http://nararenewables.org/.

2. The most recent development iteration of the social asset dataset includes an initial measure of political capital. However, this capital is still being assessed. Preliminary findings are available per request.

3. Rent-seeking groups include political, labor, professional, and business organizations. Non-rent–seeking groups include civic organizations, bowling centers, golf clubs, fitness centers, sports organizations, and religious organizations.

4. An updated social asset database is currently in progress. Since it proved to be valid with the older data, we are confident that an updated version will perform just as well or even better. Information and data for the new version are available upon request.

References

Beierle, Thomas C. 2002. *Democracy in Practice: Public Participation in Environmental Decisions*. New York: Routledge.

Budd, William, Nicholas Lovrich Jr., John C. Pierce, and Barbara Chamberlain. 2008. "Cultural Sources of Variation in US Urban Sustainability Attributes." *Cities* 25 (5): 257–267.

Cambero, Claudia, and Taraneh Sowlati. 2014. "Assessment and Optimization of Forest Biomass Supply Chains from Economic, Social and Environmental Perspectives: A Review of Literature." *Renewable and Sustainable Energy Reviews* 36 (C): 62–73.

Cambero, Claudia, and Taraneh Sowlati. 2016. "Incorporating Social Benefits in Multi-objective Optimization of Forest-Based Bioenergy and Biofuel Supply Chains." *Applied Energy* 178 (September): 721–735.

Chambost, Virginie, Jim Mcnutt, and P. R. Stuart. 2008. "Guided Tour: Implementing the Forest Biorefinery (FBR) at Existing Pulp and Paper Mills." *Pulp and Paper Canada* 109 (7): 1–9.

Coleman, James S. 1988. "Social Capital in the Creation of Human Capital." *American Journal of Sociology* 94: 95–120.

Durkay, Jocelyn. 2017. "State Renewable Portfolio Standards and Goals." National Conference of State Legislatures. Accessed September 2017. http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.

ESRI, 2017. ArcGIS. Redlands, CA: Environmental Systems Research Institute.

Emery, Mary, and Cornelia Flora. 2006. "Spiraling-Up: Mapping Community Transformation with Community Capitals Framework." *Community Development* 37 (1): 19–35.

Feld, Steven, and Keith H. Basso. 1996. "Introduction." In *Senses of Place*, edited by Steven Feld and Keith H. Basso, 1–12. Santa Fe, NM: School of American Research Press.

Fey, Susan, Corry Bregendahl, and Cornelia Flora. 2006. "The Measurement of Community Capitals through Research." *Online Journal of Rural Research and Policy* 1 (1): 1–28.

Flora, Cornelia B., and Flora, Jan L. 2013. *Rural Communities: Legacy and Change*. Boulder, CO: Westview Press.

Florida, Richard. 2002. "The Rise of the Creative Class." *Washington Monthly*, May 15–25.

Gutierrez-Montes, Isabel A. 2005. "Healthy Communities Equals Healthy Ecosystems? Evolution (and Breakdown) of a Participatory Ecological Research Project towards a Community Natural Resource Management Process." PhD diss., Iowa State University, Ames.

Inkeles, Alex. 2000. "Measuring Social Capital and Its Consequences." *Policy Sciences* 33 (3–4): 245–268.

Jacobs, Cheryl. 2011. "Measuring Success in Communities: The Community Capitals Framework." Extension Extra. Paper 517. South Dakota State Univerrsity, Brookings.

Klamer, Arjo. 2002. "Accounting for Social and Cultural Values." *De Economist* 150 (4): 453–473.

Liedtke, Kurt. 2018. "Red Rock Gets Go-Ahead for Lakeview: Renewable Biofuels Plant to Be Constructed in Lakeview." *Herald and News*, April 15. https://www.heraldandnews.com/news/local_news/red-rock-gets-go-ahead-for-lakeview/article_253409ba-63aa-5c42-becd-ea9ac2711805.html.

Martinkus, Natalie, Greg Latta, Todd Morgan, and Michael Wolcott. 2017a. "A Comparison of Methodologies for Estimating Delivered Forest Residue Volume and Cost to a Wood-Based Biorefinery." *Biomass and Bioenergy* 106 (November): 83–94.

Martinkus, Natalie, Sanne A.M. Rijkhoff, Season A. Hoard, Wenping Shi, Paul Smith, Michael Gaffney, and Michael Wolcott. 2017b. "Biorefinery Site Selection Using a Stepwise Biogeophysical and Social Analysis Approach." *Biomass and Bioenergy* 97 (February): 139–148.

Martinkus, Natalie, Wenping Shi, Nicholas Lovrich, John Pierce, Paul Smith, and Michael Wolcott. 2014. "Integrating Biogeophysical and Social Assets into Biomass-to-Biofuel Supply Chain Siting Decisions." *Biomass and Bioenergy* 66 (July): 410–418.

Martinkus, Natalie, and Michael Wolcott. 2017. "A Framework for Quantitatively Assessing the Repurpose Potential of Existing Industrial Facilities as a Biorefinery." *Biofuels, Bioproducts and Biorefining* 11 (2): 295–306.

McKnight, Brent, and Charlene Zietsma. 2007. "Local Understandings: Boundary Objectives in High Conflict Settings." Proceedings of OLKC 2007. https://warwick.ac.uk/fac/soc/wbs/conf/olkc/archive/olkc2/papers/mcknight_and_zietsma.pdf.

Montgomery, John D. 2000. "Social Capital as a Policy Resource." *Policy Sciences* 33 (3): 227–243.

Noon, Charles E., F. Benjamin Zhan, and Robin L. Graham. 2002. "GIS-Based Analysis of Marginal Price Variation with an Application in the Identification of Candidate Ethanol Conversion Plant Locations." *Networks and Spatial Economics* 2 (1): 79–93.

Parks, Craig D., Jeff Joireman, and Paul AM Van Lange. 2013. "Cooperation, Trust, and Antagonism: How Public Goods Are Promoted." *Psychological Science in the Public Interest* 14 (3): 119–165.

Perimenis, Anastasios, Hartley Walimwipi, Sergey Zinoviev, Franziska Müller-Langer, and Stanislav Miertus. 2011. "Development of a Decision Support Tool for the Assessment of Biofuels." *Energy Policy* 39 (3): 1782–1793.

Plate, Richard R., Martha C. Monroe, and Annie Oxarart. 2010. "Public Perceptions of Using Woody Biomass as a Renewable Energy Source." *Journal of Extension* 48 (3): 1–15.

Pretty, Jules, and Hugh Ward. 2001. "Social Capital and the Environment." *World Development* 29 (2): 209–227.

Putnam, Robert D. 2000. *Bowling Alone: The Collapse and Revival of American Community*. New York: Simon and Schuster.

Putnam, Robert D., Lewis M. Feldstein, and Don J. Cohen. 2003. *Better Together: Restoring the American Community*. New York: Simon and Schuster.

Rijkhoff, Sanne A. M., Season A. Hoard, Michael J. Gaffney, and Paul M. Smith. 2017. "Communities Ready for Takeoff: Integrating Social Assets for Biofuel Site-Selection Model." *Journal of Politics and Life Sciences* 36 (1): 14–26.

The Robert Wood Johnson Foundation and the University of Wisconsin Population Health Institute. 2013. County Health Rankings National Data. Accessed April 5, 2014. http://www.countyhealthrankings.org/.

Roemer, Kelli. 2017. "Exploring the Role of Social Assets in Refinery Implementation: Using Case Study Research to Ground-Truth CAAM." Master's thesis, University of Idaho, Moscow.

Rösch, Christine, and Martin Kaltschmitt. 1999. "Energy from Biomass: Do Non-technical Barriers Prevent an Increased Use?" *Biomass and Bioenergy* 16 (5): 347–356.

Rupasingha, Anil, Stephan J. Goetz, and David Freshwater. 2006. "The Production of Social Capital in US Counties." *Journal of Socio-economics* 35 (1): 83–101.

Sultana, Arifa, and Amit Kumar. 2012. "Optimal Siting and Size of a Bioenergy Facility Using Geographic Information System." *Applied Energy* 94 (July): 192–201.

Tigges, Leann M., and Molly Noble. 2012. "Getting to Yes or Bailing on No: The Site Selection Process of Ethanol Plants in Wisconsin." *Rural Sociology* 77 (4): 547–568.

US Bureau of Labor Statistics. 2015. *Quarterly Census of Employment and Wages*. Washington, DC.

US Energy Information Administration. 2014a. "Electric Power Sales, Revenue, and Energy Efficiency Form EIA-861." Detailed Data Files. Washington, DC.

US Energy Information Administration. 2014b. "Natural Gas Annual Respondent Query System." Washington, DC.

Van Dael, Miet, Steven Van Passel, Luc Pelkmans, Ruben Guisson, Gilbert Swinnen, and Eloi Schreurs. 2012. "Determining Potential Locations for Biomass Valorization Using a Macro Screening Approach." *Biomass and Bioenergy* 45 (September): 175–186.

Wang, Jiang-Jiang, You-Yin Jing, Chun-Fa Zhang, and Jun-Hong Zhao. 2009. "Review on Multi-criteria Decision Analysis Aid in Sustainable Energy Decision-Making." *Renewable and Sustainable Energy Reviews* 13 (9): 2263–2278.

Western States Arts Federation (WESTAF). 2010. "The Creative Vitality™ Index: An Overview." Accessed April 5, 2014. http://www.westaf.org/publications_and_research/cvi.

White, Eric M. 2010. "Woody Biomass for Bioenergy and Biofuels in the United States: A Briefing Paper." General Technical Report PNW-GTR-825. Portland: US Forest Service.

Zhu, Junyong. 2015. "Task C-Conversion: Pretreatment and Aviation Teams." Northwest Advance Renewables Alliance 3rd Cumulative Report. Pullman, WA.

Chapter 7 Summary

The chapter presents the development and application of a siting decision support tool (DST) for biorefineries that combines economic and social assets. The multicriteria tool is particularly useful to aid high-tech facility siting decisions. Economic siting criteria are represented by major biorefinery operational costs (e.g., feedstock and utilities) that vary geospatially. Through assessing location-specific costs at each facility, a site may be identified that provides reduced annual operational costs, resulting in a more

cost-competitive fuel. Social criteria are characterized by the ability of communities to accept and sustain complex new industrial projects. We identify three key assets impacting project sustainability: social capital, creative capital, and human capital. We include several social asset metrics measured at the county level, such as community innovation and collective action capacity. The social asset database used in the DST represents the first quantitative model of these important nontechnical assets that is both comparative and adaptive for site selection in the United States.

We validate the strength of the selected social assets with four case studies of successful and unsuccessful biorefinery facilities sited in the US West. This case study analysis draws on interviews with key stakeholders to examine the role social assets played in the successful adoption and implementation of these industries. The findings support the selected social assets, showing they are effective proxies for assessing the presence of social, creative, and human capital. We also report on the results of applying the multicriteria DST to pulp mills in the Pacific Northwest for their repurpose potential as biorefineries. The DST provides a quantitative way to evaluate these existing facilities based on multiple location-specific siting criteria, providing a score to rank each facility based on its economic and social assets. We use the DST to evaluate ten existing mills for their fit and likely success as a repurposed biorefinery. Our analysis refines the initial list of ten sites to a few select locations. By doing so, the DST increases the likelihood of successful implementation of a repurposed biorefinery.

The DST illustrates an interdisciplinary approach to addressing economic and social barriers in bioenergy facility siting. The strength of the DST is its applicability and adaptability for use in both bio- and traditional energy plant siting decisions across the nation. By combining economic and social criteria, the DST provides industry, community, and government decision-makers with a ranked list of locations for siting high-tech plants that are more likely to have sustained economic success.

KEY TAKEAWAYS

- A multicriteria decision support tool (DST) is developed, tested and validated.
- The tool integrates quantitative measures of economic and social assets relevant to siting decisions.

- The decision support tool is instrumental in effective initial facility siting assessments.
- The tool contains social asset data for most counties in the United States, thus providing difficult-to-obtain social asset data at a national level.
- Case study findings support the use of selected social assets in assessing potential bioenergy sites.

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