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Methods, Metrics, and Indicators Available for Identifying and Quantifying Economic and Social Impacts Associated with Beneficial Reuse Decisions: A Review of the Literature

Office of Research and Development

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Sustainable and Healthy Communities
3.2.1 Tools to Assist States in Developing
Beneficial Use Determinations for Wastes
U.S. Environmental Protection Agency
Office of Research and Development
Cincinnati, OH

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Foreword

The US Environmental Protection Agency (US EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, US EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by US EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Cynthia Sonich-Mullin, Director
National Risk Management Research Laboratory

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Executive Summary

Industries in the United States generate large volumes of non-hazardous wastes, sludges, by-products, and spent materials that require disposal or other end-of-life management. Solid-waste management stakeholders are increasingly employing or researching methods for beneficial reuse of these wastes in industrial and commercial applications. The acceleration of this research, both internationally and domestically, has seen numerous organizations, such as the United Kingdom Waste Resources Action Programme (WRAP) and the U.S. Environmental Protection Agency (U.S. EPA), take the lead in presenting information depicting the various benefits and drawbacks associated with such reuse. Although the research and related policy implementation should take into account the environmental, economic, and social impacts of beneficial reuse, thus far, this field has been characterized by an extensive focus on the technical feasibility of beneficial reuse and associated environmental impacts.

To identify information and tools for evaluating economic and social impacts affiliated economically and socially acceptable forms of beneficial reuse, a review and evaluation of the existing literature on Economic Impact Assessment (EcIA) and Social Impact Assessment (SIA) of beneficial reuse. This report documents the search methodology, the results, and the conclusions of that review, with the purpose of determining the data, metrics, and methods required to identify and quantify economic and social impacts of beneficial reuse decisions. Equipped with such knowledge the U.S. EPA and other organizations can develop improved decision-making frameworks and programs to better promote beneficial reuse in U.S. communities.

The current literature review entailed searching journal literature and the Internet using terms related to various beneficial reuse materials, as well as economic and social impact assessment terms. The review identified 337 studies of interest, and these were screened and categorized based on the relevancy of their topical content. Abstracts and executive summaries were reviewed of those studies to confirm their value for meeting project objectives. Full copies of the documents that were classified as “Useful” or “Potentially Useful” were obtained and reviewed to confirm their usefulness and to extract the information relevant to this study. Upon final review, 72 sources were found to assess reuse of a wide variety of materials using several related methodologies. A majority of the sources analyzed reuse of wastewater, biosolids, and Construction and Demolition (C&D) waste (in order of decreasing frequency). SIA studies were less numerous than EcIA studies and many studies contain aspects of both EcIA and SIA (henceforth referred to as EcIA/SIA studies).

Key methods found within the literature for conducting EcIA and SIA of beneficial reuse scenarios, in order of most prevalent to least prevalent are listed below.

- EcIA methods:
  - cost-benefit analysis (CBA);
  - life cycle cost analysis (LCCA); and
  - various other methods such as hedonic valuation, contingent valuation, shadow pricing, economic input-output analysis, and cost-effectiveness analysis;

- SIA methods:
  - qualitative listing and/or description of social impacts;
  - social LCA;
  - interactive community forum; and
  - various other methods such as surveys, multi-criteria decision modeling, and Environmental Impact Statement (EIS) type analyses of alternatives.

The most prevalent metrics found within the literature for the most EcIA studies, which primarily used CBA, included the following:

- direct costs and benefits (e.g., capital and operating expenses and revenues);
- indirect costs and benefits (e.g., materials storage cost, reduced landfill disposal cost); and
- external costs and benefits (e.g., jobs created, public health or environmental impacts).

In contrast, most SIA sources listed or provided qualitative descriptions of social metrics summarizing the following:

- existing or potential public attitudes towards beneficial reuse programs;
- perceptions of risk, health, and safety; and
- type and impact of possible nuisances (e.g., odor, noise, traffic).

Estimates or qualitative characterizations for both economic and social impacts were often presented in the context of internal (direct) facility- or project-level assessments. In general, data in the literature were lacking for indirect costs and external economic impacts (e.g., estimates of effects on local industries) and social impacts outside of those related to public acceptance (attitudes and perceptions) and nuisances, which are difficult to quantify and thus appear infrequently in the literature. Rather, focus often was placed on characterizing the technical feasibility, profitability and social acceptance (through attitudes and perceptions) of establishing beneficial reuse programs and projects. However, several sources used EIS, life-cycle assessment (LCA), multi-criteria decision analysis (MCDA), and other methods for quantifying more indirect and external economic impacts and social impacts. Key metrics for these indirect and external costs are typically monetary units so that they may be added or compared with direct costs. Studies found in the literature also included non-monetary ratings/rankings or purely qualitative descriptions for indirect and external costs and/or social impacts. Regardless of the exact metric used, they all provide the value of making the broader range of economic and social impacts more visible to decision-makers and key stakeholders.

Key data gaps found, and potential research needs, are as follows:

1. Metrics and data for EcIA and SIA were often presented in the context of facility- or project-level assessments that capture only internal impacts rather than more comprehensive EcIAs and SIAs that capture both internal and external impacts. Data for characterizing non-market economic impacts of beneficial use alternatives were found to be generally lacking, as well as social impacts outside of commonly used public acceptance and nuisance metrics.

2. EcIA literature gave many examples of useful data for evaluating the benefits of reuse. However, most of it was facility- or project-level financial data rather than information on the broader range of economic impacts, such as jobs created (both spatially and temporally), tax revenue, and property value changes.
3. Gaps in quantitative data for all of the SIA categories and metrics included in this report exist and are particularly acute for the non-acceptance and nuisance metrics.
4. The lack of methods to identify impacts up front. In general, studies and sources reviewed simply start with a list of impacts that are perceived to be important, or are important to stakeholders, and then try to characterize those impacts.

Selection of a specific method(s) is not explicitly described in the much of the literature, but is likely based on the goals of the project, cost of implementing the methods, availability of data, and other factors (e.g., familiarity of researchers with different methods or tools). Using a methodology that combines quantitative and qualitative assessment of environmental, economic and social impacts followed by subjective weighting of priorities (e.g., employment versus local development), may provide a promising option for assessing beneficial reuse scenarios. Several sources present innovative ways to quantitative and/or qualitatively rank attitudes towards projects and nuisance impacts, and then to prioritize social impacts and compare aggregate scores (through multiplication of impact score times a weight) of scenarios, or to perform optimization analysis. It is recommended that additional research be performed to build on reuse-related EIS, LCA, and MCDA frameworks, and more importantly, on how they can be adapted and standardized based on beneficial reuse, in order to better assist the U.S. EPA and others in developing beneficial reuse decision-support tools and for overall promotion of the practice.

The importance of this work for communities and decision makers is it summarizes the state of available information and characterizes approaches to assessing social and economic impacts of materials decisions. Data evaluated was directly applicable to land-applied BU of waste materials and BU of construction and demolition materials use scenarios, which comprise a significant portion of the BUDs being developed. BUDs can be made more useful with additional research establishing metrics, conducting case studies and establishing data sets of actual community reuse scenarios. Future research should include the development of a frame work for applying social and economic methods identified into existing BUD decision analysis to determine how inclusion of the data impacts the existing BUD. BU of materials comprises a key component of the broader approach to sustainable materials management.

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Acronyms

AHP	Analytical Hierarchy Process
C&D	Construction and Demolition
CBA	cost–benefit analysis
CCP	coal combustion product
COD	Chemical Oxygen Demand
DMS	decision making system
EcIA	economic impact assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HDPE	high-density polyethylene
LCA	life-cycle assessment
LCCA	life-cycle cost analysis
LCI	life-cycle inventory
LCIA	life-cycle impact assessment
MCDA	multi-criteria decision analysis
MCA	multi-criteria analysis
MCE	multi-criteria evaluation
NEWMOA	Northeast Waste Management Officials' Association
NOAA	National Oceanic and Atmospheric Administration
RCA	recycled concrete aggregate
SCH	Sustainable and Healthy Communities
SIA	social impact assessment
SMM	Sustainable Materials Management
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WRAP	Waste Resources Action Programme

Key Terms and Definitions

Contingent Valuation: A stated preference (i.e., individual's specified response) economic valuation method that, in the context of environmental decision-making, is used to elicit and study individuals' willingness to pay for an environmental amenities, or willingness to accept compensation for tolerating an environmental impact.

Cost-Benefit Analysis: A decision-making aid that attempts to capture the monetary value of benefits because of the need to compare them with the costs of a project, policy, or program, which are typically expressed in monetary terms. Where benefits cannot be measured in monetary terms, subjective judgments are used to assess the benefits in relation to costs.

Direct Economic Impact: A financial cost or benefit borne by an entity that result from a project, policy or program involved in the scenario, such as reduction in cost borne by a company due to the use of recovered instead of virgin resources.

Economic Impact: Changes in economic conditions, relative to baseline conditions, that result from a new project, policy, or program.

Economic Impact Assessment: Characterizing (quantitatively or qualitatively) direct, indirect and external impacts that result from a project, policy, or program.

Environmental Impact Statement: A document required by the National Environmental Policy Act that formulaically describes and analyzes a proposed action that may have a significant impact on the environment.

Full-Cost Accounting: Accounting for all of the direct and indirect monetary cost of resources used or committed to programs, which may differ from [current] direct cash outlays.

Hedonic Valuation (Pricing): A revealed preference (i.e., related to consumers' behavior and market decisions) economic valuation method that, in the context of environmental decision-making, is used to estimate the value of environmental amenities that affect prices of marketed goods. Property prices are commonly used as proxies for the value of environmental amenities based on the assumption that people value such amenities and, thus, property prices will reflect the value of a set of environmental characteristics.

Indicator: Something that shows the condition, state, or level of something, may be qualitative or quantitative and is generally based on a fact or trend.

Indirect Economic Impact: An effect of a scenario on parties not immediately involved in the scenario, such as the effect of industrial relocation on a town's tax revenue.

Life-Cycle Assessment: A method of assessing environmental impacts associated with a product's life stages, from raw materials extraction through production, distribution, use, and end-of-life management.

Life-Cycle Cost Analysis: Determines the cost-effectiveness of alternatives by assessing their costs through their life-cycle stages.

Life-Cycle Inventory: The second step of a typical life cycle assessment (after goal and scope definition), it catalogues flows of water, energy, and other inputs and outputs embodied in a product's life- cycle assessment.

Life-Cycle Impact Assessment: The third step of a typical life-cycle assessment, it assesses the environmental impacts associated with the life-cycle inventory flows.

Market Economic Impact: An impact to resources that are bought and sold in commercial markets and that can be used to assign monetary value to human health and mortality, environmental amenities, and ecosystem services.

Metrics: application of statistical and mathematical analysis to a field of study, quantitative.

Multi Criteria Analysis: A technique for use when there are several potential benefits and each is expressed in its own units. Unlike cost-benefit analysis, which has a common monetary unit, the benefits cannot be simply added together. Thus, weighting factors must be applied to the multiple benefits so that the total benefit may be summed. Weighting factors may be derived in several ways, such as asking individuals (public), asking topic matter experts, or asking the decision makers. In effect, the weighting factors can be viewed as "prices" relating the importing of different benefits, but the end result is non-monetary.

Non-Market Economic Impact: Impacts to resources not traded in the market (e.g., the effects on human health and mortality, the loss of amenity from the environment, and impacts on ecosystems and species).

Shadow Pricing: A technique used to price an intangible item for which there is no ready market from which to derive a price. In the context of environmental decision-making, shadow pricing typically uses the cost of pollution control as a proxy for valuing environmental goods and services (e.g., clean air and water).

Social Impact Assessment: The systematic appraisal of impacts on the quality of life of individuals and communities as a result of a proposed policy, project, or program. Qualitative and quantitative indicators of social impact are typically used and presented in manner that can be understood by decision-makers and individuals.

Social Return on Investment: A method for estimating the environmental and social value of scenarios.

1. Introduction

1.1 Background

Industrial, mining, agricultural, commercial, and municipal activities in the United States produce large volumes of non-hazardous solid wastes. According to the U.S. Environmental Protection Agency (U.S. EPA, 2012a), the industrial sector alone generates more than seven billion tons of non-hazardous solid wastes, which are disposed of in landfills. Because these waste materials represent valuable commodities that can be recycled, there is an ongoing effort to decrease the amount of these materials that are disposed and instead focus on non-disposal materials management options.

Beneficial reuse of large-volume waste materials is a key part of U.S. EPA's Sustainable Materials Management (SMM) effort. SMM is a systems approach that seeks to reduce materials use and their associated environmental impacts over their entire life cycle, starting with extraction of natural resources and product design and ending with decisions on recycling or final disposal. This approach helps to identify waste materials (e.g., industrial materials) as commodities that can be utilized and that are anticipated to grow key industries and associated jobs. U.S. EPA recently completed a beneficial use state of practice report for the beneficial reuse of these industrial waste materials in the United States (2012b). According to the report, although data to estimate the amount and type of beneficial reuse activities in the United States are limited, a database published by the Northeast Waste Management Officials' Association (NEWMOA) included more than 1,100 active cases of beneficial reuse data in 2011 (NEWMOA, 2012). The NEWMOA database also highlighted that beneficial reuse cases involving coal ash were most frequently reported, while other large-volume industrial wastes, including foundry sand and wood ash, were commonly reported (U.S. EPA, 2012b).

The U.S. EPA's SMM effort is part of the larger research project Sustainable and Healthy Communities (SHC). The SHC research action plan seeks to find ways to integrate environmental, economic, and social considerations into decision-making processes at various levels of management (e.g., federal, state, local). The beneficial reuse of waste materials is an important component of the SHC program. Similar to the SMM effort, the broader SHC program is expected to result in numerous benefits, including decreasing the use of virgin materials in products or processes; economic development opportunities for material recyclers; and social benefits. In addition to its benefits, economic, social and environmental impacts may result from beneficial reuse of materials. Thus decision-makers for beneficial reuse projects and proposals must balance the objectives of promoting waste materials reuse with the need to protect human health and the environment, as well as to minimize any negative economic or social impacts.

The U.S. EPA has applied its expertise and methods for identifying and quantifying the basic costs and environmental impacts for beneficial reuse applications; however, knowledge of the type of data, metrics, and methods of analysis needed to identify and quantify broader economic and social impacts for such decisions is not yet well-established. There is a current need for information and tools to identify economically and socially acceptable forms of waste reuse to assist in the beneficial reuse determination by communities, states, and federal agencies. This report presents the results of an effort to support SMM and SHC program objectives for beneficial reuse of waste materials. The current document outlines methods and metrics to identify and characterize potential economic and social impacts that were identified through a review of the literature.

1.2 Objectives

The primary goal of this project was to identify the data, metrics, indicators, and methods currently being used to quantify (i.e., measure/evaluate) the economic and social impacts of beneficial reuse and other environmental decisions. Such information is critical for providing a comprehensive, sustainability-based assessment of beneficial reuse projects. The results of this type of assessment are

necessary to provide information to support decision-making by regulatory bodies at the federal, state, and community levels.

The project objectives were to identify up-to-date, comprehensive, accurate, and well-documented data, metrics, and methods available to quantify potential economic and social impacts. Specifically, the aim was to conduct a literature review and prepare a report describing economic and social data, metrics, and methods that may be useful for supporting beneficial reuse decisions. This project did not involve direct measurement of environmental conditions, collection of environmental samples, or laboratory analysis.

The current project entailed:

- Searching the literature for economic and social data, metrics, indicators, and methods that may be useful for characterizing beneficial reuse impacts;
- Developing a database to store the information on studies identified during the literature search;
- Analyzing which methods and metrics (e.g., direct and indirect costs, nature of potential employment, social nuisance factors) appear most and least frequently within the literature; and
- Identifying data gaps and research needs.

The remainder of this report is organized into five sections. ***Section 2*** presents the literature review and documentation methodology. ***Section 3*** reviews the results and includes descriptions of studies that best illustrate key socio economic impact assessment methods (a subset of those presented in **Appendix A**). ***Section 4*** provides discussion of the results, data gaps, and recommendations. **Appendix A** provides information on studies that were found to be useful and that deal with beneficial reuse. A database of all information collected as part of this literature review was also prepared as part of this project and provided to U.S. EPA as a separate deliverable. **Appendix B** provides a description of this database.

2. Methodology

A comprehensive literature review was conducted, including source collection and data processing, to gather and extract the relevant information from recent studies, research, and/or case studies regarding the identification and characterization (quantitative and qualitative) of economic and social impacts associated with environmental decision-making. While the literature review was scoped to include resources to identify and characterize economic and social impacts as related to environmental decision making in general, priority was given to resources and information that are specific to beneficial reuse of materials and/or materials management.

The following subsections provide details on the review's source collection, which included defining search criteria and the process of searching bibliographic databases, the Internet, and webpages for specific materials and organizations, and data processing, which entailed developing criteria and procedures for evaluating sources identified and compiling references and related information in a searchable database. It should be noted that this project did not include the development of data, methods, or metrics for characterizing economic and social impacts. Instead, this project relied solely on secondary data available from scientific and commercial literature, as well as non-published literature. All non-published data sources used in the report were subjected to the criteria listed in the U.S. EPA Office of Research and Development National Risk Management Research Laboratory Requirements for Secondary Data Projects. In addition non-published research in the report is identified and any significant limitations to the data/information are reported. When possible, copies or links to documents identified during the literature search were included in the database, which was packaged with the limited-access documents as a separate deliverable.

2.1 Literature Review

2.1.1 Source Collection

Source collection for the literature review was broken down into a bibliographic journal search and an open Web and targeted search in order to also capture grey literature. In general, the search consisted of the following steps:

1. Defining keywords to use as search terms (see **Table 1)**.

Table 1. Keywords Used in the Literature Search

Beneficial Reuse Terms	Economic and Social Impact Assessment Terms
• "Beneficial use or reuse or recycling or recycled & impact or impact assessment or impact evaluation or/and impact metrics & economic or social" • "Waste or ash or residue or dust or sludge or slag or sand or reclaimed or residual or sweeping or biosolids or byproduct or asphalt or soil or tire or sediment or glass or auto fluff or salvaged & beneficial use or reuse or recycling or recycled & impact or impact assessment or impact evaluation or/and impact metrics & economic or social"	• "Impact assessment or impact evaluation or/and impact metrics & economic or social" • "Social Return on Investment or SROI & economic or social or cost" • "Beneficial use or reuse or recycling or recycled & impact or impact assessment or impact evaluation or impact metrics or decision making or decision support & economic or social" • "Life cycle or LCA & economic or social or cost"

2. Using keywords to conduct searches of bibliographic databases, including: ScienceDirect; Web of Science (including Science Citation Index Expanded and Social Sciences Citation Index); GreenFILE; EBSCO Science and Technology Collection; and Environmental Sciences and Pollution Management.

3. Performing open Web searching (on Google) using the following subsets of keywords:
   - "Reuse" and "social" and "impact"
   - "Reuse" and "social" and "impact assessment"
   - "Reuse" and "economic" and "impact"
   - "Reuse" and "economic" and "impact assessment"
   - "Waste reuse economic impact"
   - "Waste reuse social impact"
   - "EIS [Environmental Impact Statement] social indicators"
   - "Reuse bottles social impact"
   - "Biosolids reuse EIS"
   - "Biosolids reuse social"
   - "Construction and demolition waste reuse social"
   - "Construction and demolition waste economic benefits"
   - "Reuse electronics social benefits"
   - "FGD gypsum reuse soils economic"
   - "Reuse furniture economic"
   - "Reuse metal economic"
   - "Reuse remediated soil economic"
   - "Reuse tires economic"
   - "Reuse wastewater social"
   - "Reuse wastewater EIS."

   Generally, a search returned between 40 and 90 Google results for consideration, and the same searches were often performed using Google Scholar to narrow down the results. These permutations of social or economic and material terms were chosen to reflect how EISs are a good resource for certain types of materials and how certain materials among those found in the primary search were more commonly associated with reuse social or economic considerations (e.g., the latter being more prevalent within the literature of reuse of industrial-type goods, such as metal). As previously stated any grey literature used in the report has been identified and any significant limitations or biasness of the information/data is discussed.

4. Performing targeted Web searches and visiting the sites of non-profit, academic, professional society, local government, state government/agencies, national government/agencies, international work groups/organizations/agencies, and for profit institutions that were identified as performing work in the area of social and economic analysis of beneficial resue, such as the following:
   - Association of State and Territorial Solid Waste Management Officials
   - Environmental Research and Education Foundation
   - Institute for Southern Studies
   - International Association for Impact Assessment
   - Inter-Organizational Committee on Guidelines and Principles for Social Impact Assessment
   - Japan Environmental Management Association.

- Northeast Waste Management Officials' Association
- Solid Waste Association of North America
- U.S. EPA's National Center for Environmental Economics, Office of Research and Development, Office of Resource Conservation and Recovery, and Office of Air Quality, Planning, and Standards
- United Nations Environment Programme (UNEP)
- United States Agency for International Development (USAID)
- World Bank

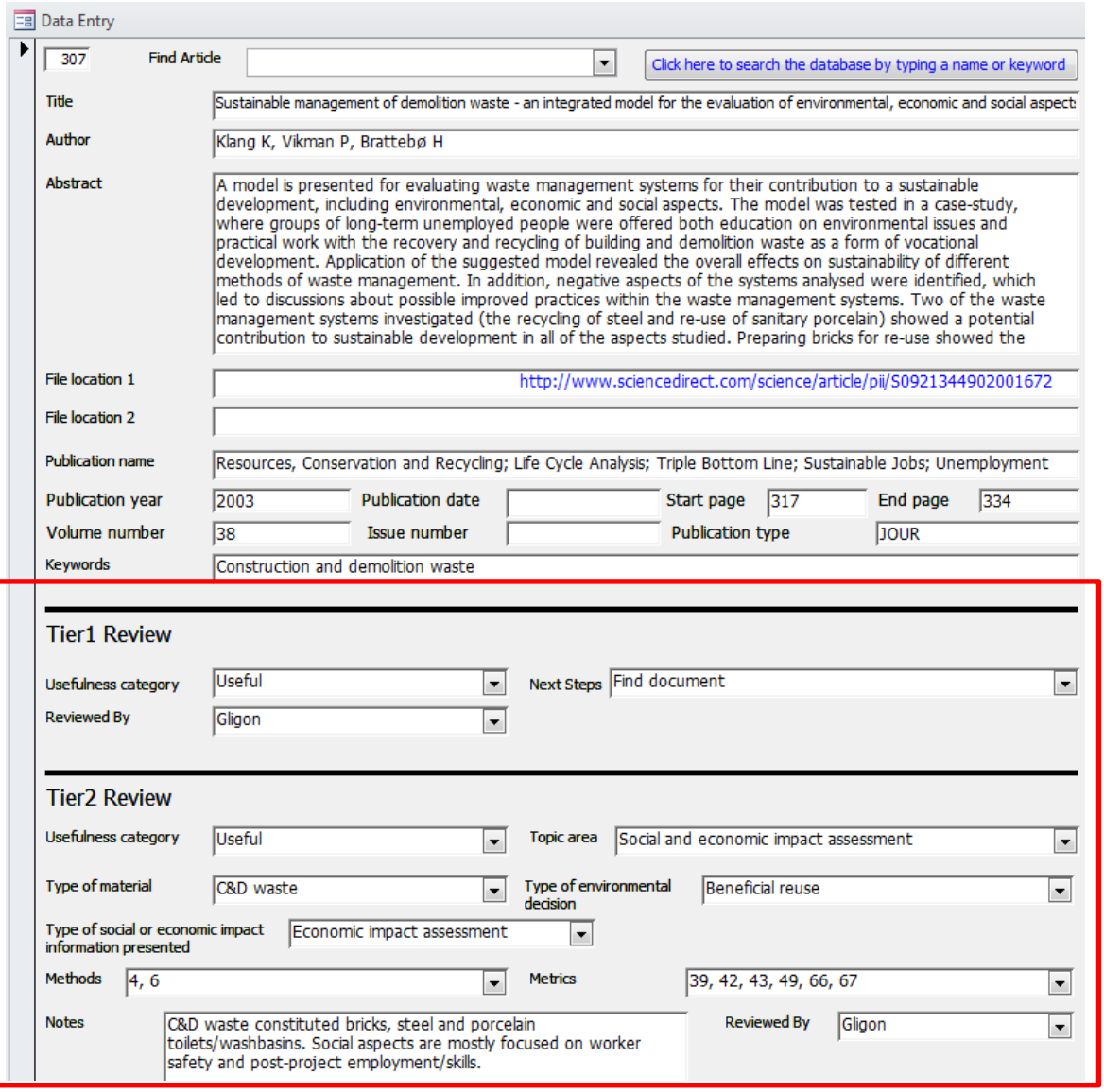
The same keywords used for the open Web search were also used to search the websites of these organizations. In particular, lists of publications whose links were available through the sites were reviewed.

2.1.2 Data Processing

Descriptor information (such as author and abstract) for studies captured by the bibliographic search was automatically uploaded into a Microsoft Access database, while descriptor information for the Web search results was transcribed manually. **Figure 1** presents the database's Data Entry form, which serves as the template for manually entering descriptor text for the Web search-acquired sources, as well as text regarding content evaluation for all sources. Evaluation text was entered into the form's Tier 1 Review and Tier 2 Review blocks in (see red box in Figure 1) by the assigned literature review coordinators. These entries required the review coordinators to assess and determine the following information for each study:

- Topic area—Social Impact Assessment (SIA) and/or Economic Impact Assessment (EcIA);
- Type of environmental decision—beneficial reuse, land use decision, or waste disposal options;
- Type of material (if focused on beneficial reuse);
- Type of social or economic impact information presented (usually "methods or metrics");
- Usefulness category—"Follow-Up," "Not Useful," "Potentially Useful," or "Useful"; and
- Methods and metrics—specific type of impact assessment and potential reuse-related indicators, respectively.

Figure 1. Access Database Data Entry Form



2.2 Evaluation Process and Criteria Used to Select Useful Sources

After completing the literature search and gathering all of the basic study information, it was necessary to develop evaluation criteria and screening methods to select those sources that were most valuable. Two screening procedures were developed to evaluate the usefulness of the identified literature, referred to as Tier 1 and Tier 2 reviews.

2.2.1 Tier 1 Review

For the Tier 1 review, the abstracts and sources were categorized as "Useful," "Potentially Useful," "For Follow-up," or "Not Useful." The breakdown of these categories is as follows:

- "Useful" indicated that the study's abstract (or introduction section within their Web pages) directly provided specific information on economic and social impact assessment methods, metrics, and/or data in relation to beneficial reuse, or to land-use or waste-disposal options (environmental decision-making) related to such reuse.

- "Potentially Useful" indicated that the study's abstract implied that the full-text included the previously described specific information. Information for identifying and characterizing social impacts for beneficial reuse and environmental decision-making was found to be very limited; therefore, exceptions were made for studies whose abstracts referenced SIA frameworks outside of the environmental decision-making context. These studies were labeled "Potentially Useful" throughout all review tiers.
- "For Follow-up" studies were those studies whose usefulness could not be confirmed by reviewing their abstracts or those for which abstracts (or full texts at Tier 2 review) were not available.
- "Not Useful" studies were those whose abstracts did not describe beneficial reuse, economic or social impacts.

Standard categories were developed for assigning methods and metrics, as a general lack of consistency in how metrics and methods were named was found throughout the literature. Based on the review of abstracts, a classification grouping for EcIA and SIA methods was developed to determine which types of methods were commonly represented within the sources. The methods for evaluating beneficial reuse were grouped as follows:

- **Interactive Community Forum:** This classification refers to sources that seek individuals' and community judgments of social impacts that may result from policy, project, or program alternatives in an environmental-type impact assessment (Becker et al., 2003)
- **Life Cycle Assessment – Social:** This classification refers to sources that used LCA based methods to capture potential social impacts
- **Cost-Benefit Analysis – Economic:** This classification refers to sources where direct and/or indirect costs were assessed,in addition to sources using life-cycle cost analysis [LCCA]
- **Study-Specific:** This classification refers to sources that address economic and/or social impacts using all other standard economic methods, such as hedonic valuation and full cost accounting, as cited by the authors themselves; decision-modeling (such as multi-criteria decision analysis [MCDA]); or informally listing metrics and/or describing them qualitatively.

Social metrics were not described or named in a consistent and standard manner in the literature; thus, standardization of social metrics was necessary. The National Oceanic and Atmospheric Administration (NOAA) *Interorganizational Committee on Principles and Guidelines for Social Impact Assessment* (NOAA, 1994) was used as a starting point for standardization. The NOAA categorizes SIA variables under the following main categories: Population Characteristics, Community and Institutional Structures, Political and Social Resources, Individual and Family Changes, and Community Resources.

Further, economic and other recurring social indicators were added during the review stages by drawing from different EcIAs and SIAs, as well as other sources, such as the documents *Reuse and Recycling Systems for Selected Beverage Packaging from a Sustainability Perspective* (Albrecht et al., 2011), which provided many infrequently recorded economic metrics, and *Guidelines for Social Life Cycle Assessment of Products* (UNEP, 2009), which presented a 31-indicator framework that mostly focuses on workers' conditions. Indicators are called "Subcategories" and are grouped by stakeholder type (i.e., worker, consumer, local community, society, and value chain actors) with nine subcategories that are most comparable to the NOAA indicators. Employment-related impacts were found to be loosely defined in the literature and often based on a source's own definition. Generally, employment impacts referred to jobs related to project operations or nearby industries (e.g., suppliers). Useful definitions, as well as an example of a framework providing additional standardized economic metrics, were obtained from the EIS framework in Preston (2013).

Table 2 lists the specific EcIA and SIA metrics that were selected from the literature or developed to standardize and organize sources from the literature review.

Table 2. Economic and Social Impact Assessment Metrics and Indicators Used

Economic Metrics and Indicators	
Direct	Cost (e.g., capital, operating); employment (including short-term, long-term, local, and out of region); cost of pollution treatment/abatement
Indirect	Employment in other industries or sectors (including local and out of region); tax revenue; property value; effects on worker skills; cost-sharing; start-up difficulties, industry and government resistance or bureaucracy
External	Monetary values placed on non-market economic impacts such as environmental goods and services or health impacts.

Social Indicators	
Population Characteristics	Population change; ethnic and racial distribution; relocated populations; influx or outflows of temporary workers; seasonal residents
Community and Institutional Structures	Voluntary associations; interest group activity; size, structure, and efficiency of local government; historical experience with change; employment/income characteristics; employment/income/other equity for minority groups; local/national/regional linkages; industrial/commercial diversity; presence of planning and zoning activity
Political and Social Resources	Identification of stakeholders; interested and affected publics; leadership capabilities, governing authority, and characteristics
Individual and Family Changes	Perceptions or characterizations of risk, health, and safety; displacement/relocation concerns; trust in political and social institutions; residential stability; density of acquaintanceship; attitudes towards policy/project; family and friendship networks; concerns about social well-being
Community Resources	Change in community infrastructure; effects on Native American tribes/indigenous peoples; land-use patterns; effects on cultural, historical, and archaeological resources; effects on traffic; scenery/aesthetics; noise; odor; change in community infrastructure – housing; change in community infrastructure – services
Other Social	Recreation; behavior change; presence of an outside agency; introduction of new social classes; presence of weekend residents; changes in mechanisms for exercise of power and authority; dissimilarity in religious practice; overall community character; community cohesion; population shift – influx or loss of older/younger residents; changes in lifestyle; changes in values/customs; worker satisfaction; worker safety

2.2.2 Tier 2 Review

The **Tier 2 review** involved further categorizing the sources categorized in Tier 1 as Potentially Useful and Useful. The Tier 2 review process involved a review of the full article's text, with the same general usefulness categorization as in the Tier 1 Review, except for the distinction between Useful and Potentially Useful classification. The former was chosen to classify articles that directly provided in-depth information on economic and social impact assessment methods or metrics in relation to beneficial reuse or land reuse, often with metrics-related data or clear execution of unique methodological frameworks. "Potentially Useful," was chosen to classify articles that provided superficial description of methods and metrics or poorly-defined methodological frameworks.

2.3 Harmonizing this Impact Assessment with Similar EPA Research

The U.S. EPA's *A Framework for Sustainability Indicators at EPA* (2012c) and three other U.S. EPA reports: *The Use of The Soil Amendments for Remediation, Revitalization, and Reuse* (U.S. EPA, 2007); *Waste and Materials-Flow Benchmark Sector Report: Beneficial Use of Secondary Materials - Coal Combustion Products* (Industrial Economics, Incorporated [IEI], 2008); *Handbook on the Benefits,*

Costs and Impacts of Land Cleanup and Reuse (U.S. EPA, 2011) were reviewed to assess how well their content could inform and lead this research:

- The findings of the U.S. EPA report on soil amendments (2007) included text on treatment, application, transportation, and other costs, as well as public outreach, odor, and "community demonstration," which constitute social impacts to be recorded.
- The IEI reuse report on coal combustion products (2008) reuse report gave typical market prices for virgin materials and their coal combustion products (CCP) substitutes, as well as Economic Input Output-LCA modeling of total economic value.
- The land reuse report (U.S. EPA, 2011) framed indicators as impact measures and reuse benefits, with listing and description of many economic and social metrics.

Although these methodologies and metrics were recorded within the database, the studies themselves contain very limited and qualitative descriptions of economic and social impacts. Rather, they provide more of an analysis of the technical feasibility and basic cost aspects of beneficial reuse. Information about the broader range of economic and social impact is limited. The U.S. EPA report on soil amendment (2007) is, however, included as a case study profiled in section 3.3 of this report because it highlights the importance of considering direct costs for any beneficial reuse project.

3. Results

The initial outputs of the literature review were based on four main parameters:

1. The number of sources classified by various levels of use previously identified (focusing on Potentially Useful or Useful);
2. The number of studies for a specific beneficial reuse material
3. EcIA and/or SIA type
4. The frequency with which specific methods and metrics reported.

A total of 337 sources were initially identified and reviewed using the criteria identified for Tier 1 screening. The screening process revealed:

- 33 sources categorized as Useful
- 95 sources categorized as Potentially Useful
- 19 sources categorized as For Follow Up
- 190 sources categorized as Not Useful

Of the 19 sources categorized For Follow Up, none of the sources proved useful. The Tier 1 screening identified 128 studies were identified as Useful or Potentially Useful. The breakdown of the remaining studies based on reuse material and Impact analysis type are presented in Table 4.

As discussed in Section 2, the 128 sources identified were subjected to a more in-depth Tier 2 review of the full article text. Results from the Tier 2 review were as follows:

- 61 sources were categorized as Useful
- 32 sources were categorized as Potentially Useful
- 22 sources were categorized as For Follow Up
- 13 sources were categorized as Not Useful

After Tier 2 screening a total of 93 sources were categorized as Useful or Potentially Useful, 72 were directly related to the reuse of specific materials, and the remainder were classified as "None" (i.e., not related to the reuse of a specific material, Table 4**)**. The "None" classification was applied to studies that described general frameworks (usually SIA) or methods that did not apply to beneficial reuse or environmental decision-making. The studies were included in the results because they provide information that will aid EPA in developing EcIA and SIA frameworks for beneficial reuse decision-making (e.g., UNEP, 2009). Within the remaining 72 studies, the top three most-represented materials were wastewater (22 studies), biosolids (10 studies) and C&D waste (6 studies), with tires being the only other reuse materials to be the primary subject of more than 2 studies. Biosolids and wastewater do not represent an industrial waste, but due to the small volume of literature available they were included in the report.

Table 3. Number of Studies By Material and Impact Type

Material Type	Economic Impact	Economic & Social Impact	Social Impact	Total
Wastewater	4	15	3	22
None (General)	1	9	11	21
Miscellaneous[1]	11	3		14
Biosolids		6	4	10
C&D waste	2	4		6
Waste disposal		1	4	5
Tires	2	1		3
Coal combustion products	2			2
Land		2		2
Metal	2			2
Soil	1	1		2
Automobile shreddings	1			1
Coal ash and foundry sand/slag	1			1
FGD Gypsum	1			1
Steel	1			1
Total	**29**	**42**	**22**	**93**
Total excluding general frameworks	**28**	**33**	**11**	**72**

3.1 Economic Impact Assessment (EcIA) Methods and Metrics

EcIA involves the quantifying in monetary terms or qualitatively characterizing the broad range of economic impacts that may result from a project, policy, or program. Economic impacts can include direct costs, indirect costs borne by an entity, and external costs that are [typically] borne by society. Costs borne by entities can include direct cost outlays (e.g., materials purchase) and indirect costs (e.g., materials storage) that are typically "hidden" in general and administrative (G&A) accounts. External costs may or may not result in actual costs to an organization. Externality costing is often used to characterize environmental and health impacts (e.g., impact of water pollution on drinking water resources and subsequently public health) in order to compare such costs back with direct and indirect costs. Thus, EcIA can involve the characterization of actual financial costs and external costs that are borne by society. External costs may be characterized qualitatively using a simple descriptor, or quantitatively by assigning a monetary value through various techniques.

Based on the review of available literature it was found that most authors performed EcIA through the use of traditional CBA and LCCA, accounting primarily for the direct costs attributed to a specific facility, process, item, or activity. Indirect costs can be calculated or estimated with relative ease, such as monitoring and reporting related costs, and incorporated into EcIA. The additional data add value to an EcIA by providing a more complete picture of all costs that are or may be associated with the product, project, or program. External costs or economic impacts often relate to the [economic] effects on local industries, employment, and/or environmental/social externalities (e.g., water quality)

[1] Includes appliances, bulky waste, cell phones, clothing, electronics, furniture, paper, plastic and general recyclables, which do not constitute typical beneficial reuse materials. Sources covering reuse of these materials were captured because they provide useful information for EcIA and SIA of waste reuse.

3.1.1 Methods

The EcIA methods employed in the 72 studies, hereafter referred to as the "most useful" (i.e. relevant) studies, can generally be grouped as

- CBA (29 studies)
- Study-specific economic methods (43 studies).

CBA is a well-established practice and often-used approach to capture the monetary value of benefits (direct, indirect, and external) to compare them with the costs of a project, policy, or program, which are typically expressed in monetary terms. It is not, however, a requirement of CBA that all costs and benefits be expressed in monetary terms. Where benefits cannot be measured in monetary terms, subjective judgments are often used to assess the benefits in relation to costs. A key strength of CBA is that it attempts to avoid making subjective judgments by treating costs and benefits in common terms (i.e., monetary units). This allows for decision makers to directly compare the potential cost and benefits. A weakness of CBA may be the use of monetary terms to characterize benefits, which can oversimplify the complex nature of benefits such as their distribution among groups and/or through time. Monetization of benefits estimation is an uncertain science; however, this is a shortcoming for all techniques characterizing externalities. A variety of techniques are available to monetize non-market benefits. The most commonly found in the literature include:

- **Direct valuation techniques** aim to measure the monetary value of environment benefits. Since environmental benefits (e.g., improved air or water quality) are not bought and sold in markets, monetary valuation of such benefits is accomplished by establishing a surrogate market or by using an experimental design to express hypothetical valuations of benefits. Monetary values from existing markets or programs (e.g., pollution control costs) may also be used to as proxy values for environmental benefits.
  - Contingent valuation—CVM is based on a direct approach of asking individuals what they are willing to pay for a benefit and/or what they are willing to receive in the form of compensation to tolerate an impact. The process of asking these questions is usually done using a survey or questionnaire. Ultimately, the process aims to elicit individual's valuations for increases or decreases in a good or service, if one existed for an environmental good or service (thus "contingent"). A key strength of CVM is that it should be applicable to any circumstance, whereas other methods (e.g., hedonic or shadow pricing) may lack available cost information.
  - Hedonic valuation (Pricing)—This technique is used to estimate the value of environmental amenities that affect prices of marketed goods. Residential housing prices are commonly used to estimate the value of environmental amenities based on the assumption that people value the characteristics of environmental goods and services, thus property prices reflect the value of a set of environmental characteristics. Hedonic pricing aims to identify the impact of environmental factors on goods by analyzing price differentials that are due to a particular environmental aspect and predicting how much individuals would be willing to pay for an improvement in environmental quality and/or the social value of the improvement.
  - Shadow pricing—This technique is used to price intangible items for which there is no ready market from which to derive a price. Shadow prices are most commonly used in CBA, where some elements of the analyses cannot be quantified by reference to a market price or a cost. In the context of environmental issues, shadow pricing typically uses the cost of pollution control as a proxy for valuing environmental goods and services (e.g., clean air and water).

- **Indirect valuation techniques**, establish a relationship between pollution and an environmental effect. In contrast to direct valuation techniques, they do not try to measure direct values or preferences for an environmental good or service. Indirect techniques are often used to estimate human health impacts associated with environmental pollution, where a dose-response type relationship is calculated for a pollutant and resulting health impact. A dose-response type relationship can also be established for environmental problems (e.g., reduced crop yields, reduced water quality, or damage to infrastructure [acidification]). Calculating measures of damage range in the level of sophistication. The simplest technique is multiplying a reduction factor by the market price, such as multiplying a reduction in corn crop yield by the market price for corn. At the more sophisticated end of the range, models can be constructed to estimate the market changes in demand and supply based on a pollution prices to better account for potential changes in market price through time.

Study-specific EcIA methods include a variety of techniques designed to capture specific indirect and external cost aspects that go beyond traditional CBA or provide an alternative approach. Descriptions of commonly used techniques as found in the literature include:

- **Full-Cost Accounting**—In the accounting profession, FCA entails accounting for and assigning all monetary costs (e.g., capital, labor, administrative, regulatory, reporting) to specific products, projects, or programs. In the context of materials management, FCA is often used to describe a similar process that accounts for both the current outlays of cash and the monetary costs of resources used or committed to programs, which may not be actual cash outlays.
- **Life Cycle Cost Analysis**—This method can be viewed as an expanded CBA that aims to capture all the costs associated with purchasing and owning a product throughout its life cycle. Conducting a LCCA requires that future costs consider the time value of money because money spent (or received) will occur at different times throughout the life cycle. The strength of LCCA is that it accounts for all potential costs that may be incurred through the life of a product, instead of just the initial procurement cost. Costs associated with owning, maintaining, and decommissioning the product could be significant and provide a more complete understanding of cost beyond procurement cost. Typically, LCCA focuses on direct and indirect cost, but it may be expanded to include external costs as well.
- **Cost-Effectiveness Analysis (CEA)**—This EcIA method can be viewed as a variant of CBA, where only costs are measured in monetary terms. Benefits are simply listed and/or described in more qualitative terms, or a semi-quantitative scheme is employed to rank benefits. CEA may best come into use when the expression of benefits in monetary terms is thought to be improper or otherwise unacceptable, but such benefits need to be made explicit as part of the decision-making process.
- **Multiple-Criteria Analysis**—This method is used when there are several potential benefits (as part of CEA, for example) and each is expressed in its own units. Unlike traditional CBA, which has a common monetary unit, the benefits cannot be simply added together. Thus, weighting factors must be applied to the multiple benefits so that the total benefit may be summed. Weighting factors may be derived in several ways, such as obtaining input from individuals (public), asking topic matter experts, or asking the decision makers. In effect, the weighting factors can be viewed as "prices" relating the importing of different benefits, but the end result is non-monetary.
- **Decision Analysis**—This method generally has developed to facilitate decision making in situations where there is uncertainty about the outcomes from a project, policy, or program. In decision analysis, the aim is to assign probabilities to benefits or costs. The value of this technique is that it makes uncertainties explicit and allows for various objectives to be used. The key shortcoming is that there is no clear approach for assigning uncertainties.

- **Environmental Impact Assessment (EIA)**—This method typically requires that all impacts (positive and negative) of a project, policy, or program be assessed. Focus is placed on the environmental consequences of alternatives, and the monetization of impacts may or may not be included; thus, EIA can be thought to be encompassed by CBA. In EIA, the positive and negative consequences are listed, but no aggregation is performed to yield a total impact (or benefit). Rather, decisions are made by inspecting the listing of consequences, and the judgment values used may not be clearly defined.
- **Economic Input-Output and Economic Impact Analysis**—These are general methods that enable the inclusion of broader array of economic aspects, namely economic impacts to other associated industries or sectors.

Selection of a specific method(s) is not explicitly described in the much of the literature, but is likely based on the goals of the project (e.g., soliciting individuals' valuation of defined environmental goods and services), the cost of implementing the methods, the availability of data, and other factors. Different approaches for valuing non-market economic impacts are useful in cases where no reasonable market data or proxy data for the environmental good or service in question is available, but employing multiple approaches can be time consuming and expensive to perform.

Table 4 presents the frequency of economic metrics, by type.

Table 4 Economic Metrics and their Frequency within the Most Useful Sources

Metric	Frequency
Net cost– direct	51
Employment – direct	22
Effects on Local Industry(ies)	17
Employment – local	7
Property Value	7
Effects on Worker Skills	6
Employment – indirect	5
Willingness to pay	4
Net cost– indirect	4
Employment – short-term	3
Employment – long–term	3
Cost of pollution treatment	2
Tax Revenue	1
Cost-sharing	1
Start-up difficulties, and industry and gov't resistance/bureaucracy	1
Employment – external	0

3.1.2 Metrics

Given the predominance of CBA, and to a lesser extent LCCA and other economic impact assessment methods, it follows that direct costs (and revenues) comprised the most-cited metrics and most useful data in understanding the economic benefits attributed to reuse. Direct costs are usually presented for activities or items that are internal to a facility or project and typically include capital costs, operation and maintenance costs, and any revenues. The most detailed studies used basic CBA and LCCA to assess the financial viability of treatment processes required for reuse (typically of wastewater), while several only described selective indirect and external costs (or benefits) of reuse materials. Key metrics for these

indirect and external costs are typically monetary units so that they may be added or compared with direct costs. Studies also included non-monetary ratings/rankings for indirect and external costs or purely qualitative descriptions. Regardless of the exact metric used, they all provide the value of making indirect and external cost more visible to decision-makers and key stakeholders.

3.2 Social Impact Assessment (SIA) Methods and Metrics

According to Burdge (2004), SIA can be thought of as the systematic appraisal of impacts on the quality of life of individuals and communities as a result of a proposed policy, project, or program. SIA aims to provide qualitative and quantitative indicators of social impacts in a form that can be understood by decision-makers and individuals. Various guidelines for SIA have been developed by different organizations, such as NOAA, the World Bank, USAID, and the International Association for Impact Assessment. The NOAA framework is often quoted as a seminal work in the field of SIA. Gomez et al. (2013) considered it to be one of the two key conceptual studies, with the other being an internationally focused article (Vanclay, 2003). However, the style in which Vanclay (2003) groups indicators lends itself less-effectively as a specific usable framework compared to the NOAA framework.

The completeness and importance of the NOAA framework was illustrated in an EPA Office of Emergency and Remedial Response literature review (Turnley, 2002). The author details how NOAA drew their social indicators from a wide range of literature over the prior 15 years. Turnley (2002) also noted that the NOAA indicators were consistent with other reviewed sources, and subsequently based their social, cultural, and economic impact indicators for EPA on a modified version of the NOAA indicators. Similarly, as described in Wong (2013), Rabel Burdge—an author of the NOAA framework—developed his own list of 26 indicators with little difference from the original NOAA framework, further implying how the NOAA framework provides a standard and leading form for SIA.

SIA methods often attempt to adapt assessment methodologies that were originally designed for environmental aspects and apply them to characterize socio-economic aspects (Burge, 2004). Another key challenge with SIA is eliciting individual and collective perspectives in a meaningful and efficient way (Burge, 2004). Capturing stakeholder perspectives is an important part of SIA, though, and one that cannot only be developed in a top-down manner since they may not accurately represent the views and priorities of the impacted individuals, entities, or communities (UNEP, 2009). In general, determining which social impacts are to be covered in an assessment and the way they should be assessed and/or measured should be case and context specific. Consequently, no general consensus in the literature exists on which indicators to use and how to assess social impacts of planned interventions with SIA.

Based on the review of available literature, it was found that most authors performed SIA through a simple listing of metrics and/or by describing them qualitatively; through expert consultation and/or self-selection of impact ratings and their weights within their own criteria-based modeling of optimum reuse outcomes; or through subjective rating, such as in Padilla et al. (2013). For scenario modeling and weighting, Dehghanian & Mansour (2009) performed Analytical Hierarchy Process (AHP) modeling of reuse (for tire pulverization or incineration) using expert-led self-selection of weights for worker safety and perceptions of risk, health, and safety (as well as employment and local development), which helped calculate a social indicator score within their Expert Choice 2000 software. This common weighting process was often prefaced with subjective assessment of social impacts to accompany more quantitative LCA-type datasets, as shown in Craighill and Powell (2000), which rate land use, visual, and other impacts (caused by transportation of C&D waste in the United Kingdom, as modeled in their LCA) as low, medium, or high.

Subjective ranking and/or qualification of social impacts was also performed throughout EIS-type literature and sources, such as Goldstein and Beecher (2007), which covered a wide range of social metrics through description within paragraphs concerning "risk perceptions, outrage factors, risk communication and public participation [and] earning (public) trust." These trends of listing with

qualitative description of social metrics and assigning impact values with a low range of values (e.g., 3–5 possible rankings) are further illustrated in many of the case studies profiled in Section 3.3. Descriptions of these key and representative sources suggest ways forward for future work in determining methodologies for framing the advantages of beneficial reuse.

3.2.1 Methods

SIA methods used in the literature sources were either

- Study-specific social methods (58 studies)
- Social LCA (4 studies)
- Interactive community forum (ICF; 2 studies).

Study-specific social methods refer to studies lacking the above and other methodological frameworks (e.g., deliberately evaluating NOAA 1994 indicators) that generally consist of listing social impacts and/or describing them qualitatively. Although as shown in the case studies in Section 3.3, these methods often entailed surveys (as with the EcIA methods), modeling techniques, EIS-type analyses of project alternatives, and other tailored methods. Insightful techniques to quantify social impacts were usually not developed in these studies. This more qualitative description method may have the most potential for studies with low projected social impacts, such as those primarily focused on small-scale and/or on-site reuse of waste products, as studied in Begum et al. (2006). .

Social LCA refers to a method to assess the positive and negative social aspects of products, projects, or programs along the life cycle from the extraction and processing of raw materials to end-of-life management. Social LCA often makes use of generic and site-specific data and can be quantitative, semi-quantitative or qualitative. The resulting information can be used to complement a conventional [environmental] LCA, applied on its own or used in combination with the other techniques. The basic methodology for social LCA is expressed within Padilla (2013), as well as UNEP-type indicator evaluation, and other sources such as Sa-nguanduan and Nititvattanan (2011) and Craighill and Powell (2000). These later sources focus on wastewater reuse and C&D waste reuse, respectively, and include social indicators to compliment environmental LCA results.

Interactive Community Forum is a method created by the U.S. Army Corps of Engineers for incorporation into their EIS of alternatives for salmon recovery in a Snake River basin (U.S.) project. The method evaluates citizens' judgments about predicted impacts on their community by EIS alternatives (Becker et al., 2003). This participatory approach seems useful for projects that have anticipated large, negative social impacts, such as through traffic and odor associated with biosolids hauling and management, as understanding that the nature and extent of the public's concerns are more relevant in those cases.

3.2.2 Metrics

Table 5 presents the frequency of social metrics recorded for the 72 beneficial reuse material-specific "Potentially Useful" and "Useful" sources, as evaluated at Tier 2 review. As mentioned in **Section 2.2.1**, above, the categories of SIA variables are based on NOAA's 1994 Social Impact Assessment Framework.

Several authors analyzed social impacts of beneficial reuse through the lens of a basic SIA framework, such as that of UNEP (2009) or the social impacts-inclusive format of the U.S. National Environmental Policy Act EIS. Padilla et al. (2013), for example, used the UNEP Social LCA framework to analyze urban versus rural wastewater reuse projects in Mexico. As discussed in **Section 2.2.1**, the UNEP indicators focus primarily on workers' conditions and employment impact types (including direct and those for nearby industries). Preston (2013) gave the most detailed analysis within the standard EIS

framework by quantifying many of the impacts (usually described in qualitative terms) for proposed options for land reuse of a naval base

Table 5. Social Metrics and Their Frequency within the Most Useful Sources

NOAA Category	Metric	Frequency
Population Characteristics	Population change	2
	Ethnic and racial distribution	2
	Relocated populations	2
	Influx or outflows of temporary workers	0
	Seasonal residents	0
Community and Institutional Structures	Voluntary associations	1
	Interest group activity	1
	Size, structure, and efficiency of local government	1
	Historical experience with change	0
	Employment/income characteristics	7
	Employment/income/other equity for minority groups	11
	Local/ regional/ national linkages	3
	Industrial/ commercial diversity	1
	Presence of planning and zoning activity	2
Political and Social Resources	Distribution of power and authority	4
	Identification of stakeholders	8
	Interested and affected publics	3
	Leadership capabilities and characteristics	0
Individual and Family Changes	Perceptions of or proxies for risk, health, and safety	16
	Displacement/ relocation concerns	3
	Trust in political and social institutions	4
	Residential stability	2
	Density of acquaintanceship	0
	Attitudes towards policy/project	18
	Family and friendship networks	0
	Concerns about social well-being	2
Community Resources	Change in community infrastructure	4
	Native American tribes/indigenous peoples	1
	Land use patterns	10
	Effects on cultural, historical, and archaeological resources	4
	Traffic	10
	Scenery	8
	Noise	14
	Odor	15
	Change in community infrastructure – housing	2
	Change in community infrastructure – healthcare and other services provision	2

Table 5 cont. Social Metrics and Their Frequency within the Most Useful Sources

NOAA Category	Metric	Frequency
Other	Recreation	7
	Behavior change	3
	Presence of an outside agency	0
	Introduction of new social classes	0
	Presence of weekend residents	1
	Changes in mechanisms for exercise of power and authority	0
	Dissimilarity in religious practice	0
	Overall community character	0
	Community cohesion	3
	Population shift – influx or loss of older/younger residents	0
	Changes in lifestyle	0
	Changes in values/customs	0
	Worker satisfaction	4
	Worker safety	8

3.3 Case Studies

Selected case studies, from the literature review, employing EcIA and SIA are summarized to provide insight into different methods and metrics used, how and why those methods and metrics were chosen, and if and how they are used to support decision-making. Note that many studies contain elements of both EcIA or SIA, with each presented in varying levels of detail and quantification, and these are referred to as EcIA/SIA studies. These and additional case study examples are provided in **Appendix A**. The appendix lists and summarizes all case studies covering EcIA and SIA methods and metrics found in the literature that were specific to beneficial-reuse topics. The studies discussed in the sections below were selected for inclusion in Appendix A because they best illustrate the application of the most commonly used economic and social methods and metrics.

3.3.1 Combined EcIA/SIA Studies

EcIA/SIA Case Study 1: Youngqist & Goldberger (2013) a Summary Report: a Survey of Skagit County Residents: Opinions about Local Reuse and Recycling of Biosolids Compost.

Youngqist, C.P., and Goldberger, J.R. (2013). A summary report: a survey of Skagit County residents: opinions about local reuse and recycling of biosolids compost. http://www.laconner.net/uploads/Skagit%20Biosolids%20Survey%20Summary%20Report%20by%20Caitlin%20Price1.pdf

Material and Context: "Class A" biosolids reuse in a composting research project at the wastewater treatment plant in Skagit County, Washington.

Methods: Using the Tailored Design Method in Dillman et al. [2009], mail surveys were collected from 1,374 households. Respondents received a pre-notification letter, first questionnaire, postcard reminder, and replacement questionnaire over the course of an 8-week data collection period.

Metrics**:** Odor; attitudes towards policy/project; concerns about social well-being and perceptions of risk, health, and safety; economic impacts on local industries.

How Methods and Metrics were Selected and Used to Make Decisions: Survey questions (related to metrics) were chosen to better understand "residents' attitudes, opinions, and knowledge about the use of 'Class A' biosolids and to explore potential correlations between attitudes about biosolids and the demographics and lifestyle choices of respondents." Response data for the questions were given as mean scoring, scaled 1 (not concerned) to 5 (very concerned). This approach provided a simple means of eliciting public perceptions, concerns, and values surrounding the issue (in this case biosolids use). Although specific analysis or assessment was not performed to determine an overall result, the findings can be useful for informing officials about the key economic, environmental, and social concerns that may require additional attention or characterization.

Key Findings and Notes: This study did not attempt to draw conclusions about potential economic or social impacts. The authors elected to compile the data and discuss the survey results. The complied survey results indicated that residents were more concerned about public and environmental health than loss of property value and odor.

EcIA/SIA Case Study 2: Sa-nguanduan and Nititvattanan (2011) Strategic Decision Making for Urban Water Reuse Application: A Case from Thailand.

Sa-nguanduan, N. and Nititvattananon, V. (2011). Strategic decision making for urban water reuse application: A case from Thailand. *Desalination 268*(1-3): 141-149.
http://www.sciencedirect.com/science/article/pii/S0011916410007253

Material and Context: Proposed wastewater reuse in options in Pattaya, Thailand. The potential reuse options included six scenarios: landscape irrigation in public areas; irrigation in household areas; toilet flushing; industrial application; blending with drinking water supply; and recreational/environmental uses (e.g., within lakes or ponds).

Methods: Contingent valuation was used to elicit the public's willingness to pay for improved water resources and willingness to accept payment for tolerating decreased water resources or quality. Survey questionnaires were given to 200 households, and interviews were conducted with 33 local and central government officials and researchers.

Given the stated importance of stakeholder opinion, significant effort was put into engaging primary (city, producer, and consumer), secondary (government environmental, industrial, and other related department), and tertiary (educational institution and non-governmental organization) stakeholders and eliciting their environmental, economic, social, and technical interests.

Data analysis was conducted using the "importance order of criteria method" to score and then rank reuse scenarios. This process entailed summing the product of the assigned weight of each individual criterion (14 in total) by its rank value as assessed by the authors (often based on public/key interviewee's opinions) for all criteria for each of 6 wastewater reuse scenarios. The reuse scenario score/sum was ranked from highest to lowest score (most to least favorable option.

The authors evaluated the survey and interview results using 4 different weighting models, to evaluate the impact of weighting all factors evenly, or emphasizing a specific aspect, either technical/economic, social/environmental, or interviewee responses.

Based on the weights and assessed values for each criteria and summing them for each of the 6 alternatives, the reuse options were then ranked 1 (best) through 6 (worst) for each of four models. Sensitivity analysis was also conducted to determine the effects on rank based on increased water demand and tap water price, and decreased water demand.

Metrics: Direct costs and willingness to pay for externalities; elicited public values towards policy/project and perceptions of risk, health, and safety.

How Methods and Metrics were Selected and Used to Make Decisions: The survey interview and public questionnaire methods were developed to efficiently generate semi-quantitative stakeholder and public opinion responses that could be converted into scaled data compatible with the importance order of criteria methodology. The weighting methodology was utilized to give the authors the opportunity to observe differences in ranking (suggesting which decisions are best given the local context) based on weighting the importance of specific aspects (Table 8). The interviewee model (Model 4) facilitated a major purpose of the paper, which was to ensure that reuse decisions would be based on technical cost information, and the opinions of stakeholders. Direct costs and willingness-to-pay were analyzed because they represent the actual financial outlays necessary for wastewater reuse implementation and the best indicator for valuing the environmental and other aspects not captured by direct cost, respectively.

Key Findings and Notes: For the economic and technical considerations-only weighting scenario (Model 2), the status quo of landscape irrigation in public areas ranked the highest, due in part to how the potential for institutional cooperation was judged to be the highest for this scenario. For all other models, industrial reuse ranked the highest (Model 1), given how it was generally judged to be the best economic and social scenario. Recreational/environmental uses and blending with drinking water supply were consistently the lowest-ranked alternatives (Model 3). Additionally, several metrics revealed interesting public/interviewee opinions, such as how the willingness to pay for reused wastewater was 31% of the tap water price.

EcIA/SIA Case Study 3: Donalson et al. (2010) Sustainable Assessment of Recycled Concrete Aggregate (RCA) Used in Highway Construction.

Donalson, J., Curtis, R. and Najafi, F. (2010). ***Sustainable assessment of recycled concrete aggregate (RCA) used in highway construction*****. http://docs.trb.org/prp/11-0492.pdf .**

Material and Context: C&D waste (concrete) substitution of virgin limestone for road base aggregate in a project in Winter Haven, Florida.

Methods: LCCA for cost/economic consideration; LCA for select (e.g., carbon emissions) environmental consideration; and assessment of leachability as a proxy for social considerations.

Metrics: Direct and indirect costs; net energy consumption and carbon emissions; and leachability.

How Methods and Metrics were Selected and Used to Make Decisions: No description was provided as to why specific methods and metrics were selected for use. The LCCA method was adopted from the Recycled Materials Resource Center (RMRC, 2012) which analyzed basic acquisition, delivery, installation, and maintenance costs determined, in this case, through consultation with a local construction company. Select LCA data were developed, via the EPA WARM tool, to provide an estimate of the net life cycle energy and carbon emissions, as well as an overall view of potential tradeoffs in environmental impacts between the recycled and virgin aggregate. Social impacts were determined to be important to consider and the authors determined that use of leachability of pollutants from the road base material served as a meaningful proxy for potential public-health issues.

Key Findings and Notes: Recycled concrete aggregate was found to be more cost-effective than virgin limestone aggregate for price of delivery and installation, as well as annual life-cycle cost (equivalent to delivery cost times capital recovery cost plus annual maintenance cost). This finding was due in large part to how virgin material transportation required 30 miles more travel compared to recycled aggregate transportation. Overall, the LCA results found recycled aggregate to be preferable to virgin aggregate, while the leachability assessment determined that both recycled and virgin aggregate were socially acceptable.

EcIA/SIA Case Study 4: Mediterranean Wastewater Reuse Working Group (2007) Mediterranean Wastewater Reuse Report.

Mediterranean Wastewater Reuse Working Group (2007). *Mediterranean wastewater reuse report*. http://ec.europa.eu/environment/water/water-urbanwaste/info/pdf/final_report.pdf .

Material and Context: Wastewater reuse for agriculture, livestock, industry and power generation, urban irrigation/landscaping, and groundwater recharge in Mediterranean and other contexts.

Methods: LCCA.

Metrics: Direct costs and employment; identification of stakeholders; concerns about social well-being; recreation; and attitudes towards policy/project.

How Methods and Metrics were Selected and Used to Make Decisions: The cost methodology was chosen because it was perceived to be a useful way to evaluate the conditions under which treated wastewater reuse can be cost-effective and also to compare and contrast cost performance of competing options. Direct costs were presented for each scenario quantitatively as a function of capacity and end-use quality/other requirements. In contrast, potential social and health risks and benefits were described qualitatively, in the commonly encountered bullet-point style, and did not contribute insightful commentary or analysis.

Key Findings and Notes: No specific conclusions about the preference or ranking of wastewater reuse options were provided. Rather, the authors presented a range of published (from Asano, 1998) cost estimates by reuse option as a method of assessing economic costs-benefits. Advanced treatment for agriculture, livestock, industry, and landscaping use were associated with full annual costs of $7.4 to $27.9 per ft^3 (for 1.4 million ft^3 to 141,000 ft^3 per day flow, respectively)[2], as taken from Asano (1998). European and U.S. case studies demonstrating treatment costs were also presented.

Key Findings and Notes: C&D reuse and recycling was estimated to be profitable at the site, with net benefits equivalent to 2.5% of the total project budget. With respect to the more intangible costs, or externalities, judgment was used to determine that the external benefits outweighed the external costs and, thus, a net external benefit would be achieved.

EcIA/SIA Case Study 5: Begum et al. (2006) A Benefit–Cost Analysis on the Economic Feasibility of Construction Waste Minimisation: The Case of Malaysia.

Begum, R.A., Sewar, C., Pereira, J.J., and Jaafar, A.H. (2006). A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia. *Resources, Conservation and Recycling, 48*(1): 86-98
http://www.sciencedirect.com/science/article/pii/S0921344906000139

Material and Context: C&D waste reuse and recycling at a project site in Malaysia.

Methods: CBA, based in part on surveys of industry leaders for basic cost data.

Metrics: Direct and indirect costs; externalities (noise, odor, and worker safety).

How Methods and Metrics were Selected and Used to Make Decisions: The authors selected CBA because they perceived it to be one of the standard techniques for measuring profitability and could assist in their major goal of determining economic feasibility of C&D reuse. This was a common theme throughout the major goal of the majority of the 72 "most useful" studies identified as part of the literature review conducted for this project. They did not attempt to quantify externalities, but instead opted for a more simple assessment (based on judgment) of whether externalities were positive or

[2] Values presented were converted from Euros to Dollars (1.00 Euro = $1.35 values based on July, 2014 conversion rate) and from metric to US standard.

negative for the proposed project. Using such a simple approach for characterizing environmental and/or social externalities may constitute a weakness, but it also is much easier and cheaper to implement than an effort to quantify the externalities via a survey or other mechanism. In addition, since the focus was on the economic feasibility, the use of a qualitative evaluation of externalities at a minimum makes their consideration more explicit.

Direct and indirect cost metrics, determined when preparing the survey of industry leaders, included benefits such as purchasing cost savings; re-sale revenue; waste collection cost savings; and landfill charge savings, and costs such as those for collection and separation, equipment purchase, storage, and transportation.

Key Findings and Notes: C&D reuse and recycling was estimated to be profitable at the site, with net benefits equivalent to 2.5% of the total project budget. With respect to the more intangible costs, or externalities, judgment was used to determine that the external benefits outweighed the external costs and, thus, a net external benefit would be achieved.

EcIA/SIA Case Study 6: Craighill & Powell (2000) A Life Cycle Assessment And Evaluation of Construction and Demolition Waste.

Craighill, A., and Powell, C. (2000). A life cycle assessment and evaluation of construction and demolition waste. http://www.cserge.ac.uk/sites/default/files/wm_1999_03.pdf.

Material and Context: C&D waste management in the United Kingdom. Scenarios included reuse on site (through crushing and usage as building foundation or road/parking lot base), landfill disposal; 50:50 mixes of either landfilling and off-site recycling or reuse and recycling; or evenly allocating one third of total waste among all three options.

Methods: LCA; full cost accounting; contingent valuation and other techniques for externalities; multi-criteria evaluation (MCE) analysis modeling. Social impacts (land use, visual and noise) were qualified as low, medium, or high and then converted to numerical scores of 1, 2 or 3, respectively, for inclusion with quantitative LCA data. Literature review and expert/industry consultation via 9 site visits were used to collect data to value direct financial costs (e.g., transportation, landfilling) .

In addition, willingness-to-accept estimates were collected for characterizing the externality costs of tolerating mining and other operations associated with primary aggregate production. Social impacts considered included casualties, jobs, noise and traffic, scenery, and odor, listed in order of descending weight. These estimates were combined with a subjective weighting of all [20] impacts within four weighting schemes: 1) equal weighting for cost and resources such as energy, water, etc., 2) 100% weight on internal cost, 3) social-heavy weighting, 4) environmental-heavy weighting.

The weighting process was executed in the MCE using HIVIEW software (2014) that permits the usage of non-monetary and qualitative decision criteria.

Metrics: Author- or literature review-based subjective quantification or qualitative valuation of health, risk, and safety; land use patterns; scenery; noise; traffic and odor; direct and indirect costs; and employment.

How Methods and Metrics were Selected and Used to Make Decisions: The reasoning for the selection and formation of the overall LCA methodology was not explicitly given, except for the concluding statement that "by using a technique such as lifecycle assessment, a number of alternative waste management strategies can be judged against a range of environmental, social and economic criteria." The benefit of LCA is that it provides a standard framework for evaluating environmental impacts and other potential tradeoffs among alternative waste management options or strategies.

A more qualitative LCA was performed using a low/medium/high ranking scale, which were translated into 1, 2, and 3 numerical values respectively. This more qualitative ranking was viewed as being adequate for facilitating comparisons and emphasizing rather than quantifying specific impacts. Clarification was given that the ranking scale was sufficient since impacts were more directly associated with a site proper, rather than with its throughput; therefore, they reflect a "fixed externality" rather than a "variable externality." Quantitative LCA results were also compiled from literature sources and included measures for traffic (in km), malodorous air (in m^3), jobs (person-days), and land use, scenery (visual), and noise impacts.

Key Findings and Notes: Landfill disposal or reuse generally rated better in land use, visual, and noise impacts than combination of options. Reuse rated best for odor, minimized external cost, and every component of the triple bottom line, but worst for job creation. However, based on the weight schemes used, reuse ranked the highest in all schemes while landfilling consistently ranked the lowest.

3.3.2 EcIA Studies

EcIA Case Study 1: Molinos-Senante et al. (2011) Cost–Benefit Analysis of Water-Reuse Projects for Environmental Purposes: A Case Study for Spanish Wastewater Treatment Plants.

Molinos-Senante, M., Hernández-Sancho, F., and Sala-Garrido, R. (2011). Cost–benefit analysis of water-reuse projects for environmental purposes: A case study for Spanish wastewater treatment plants. *Journal of Environmental Management 92*(12): 3091-3097. http://www.sciencedirect.com/science/article/pii/S030147971100288X

Material and Context: Wastewater utilized at 13 reuse projects in Spain.

Methods: LCCA; shadow pricing for environmental externalities.

Metrics: Direct and indirect costs; external costs using pollution control cost as a proxy.

How Methods and Metrics were Selected and Used to Make Decisions: The authors selected internal facility and financial cost metrics combined with estimates of external pollution costs based on the stated need to use conventional methodology (e.g., CBA). Usage of the shadow pricing technical to value externalities was justified for how it provides a cheaper alternative compared to developing and administering willingness-to-pay type surveys for contingent valuation. The use of pollutant control costs as shadow prices for environmental attributes and quality provided a methodology to assess the economic viability of wastewater treatment technologies that considered internal and external impacts. Although the methodology is not new, it does further point to the trend towards demonstrating economic viability as a crucial (if not the only) prerequisite for scaling up reuse projects.

Shadow prices for suspended solids, nitrogen, phosphorus, and chemical oxygen demand (COD) pollution of -$0.010, -$21.60, -$50.60, and -$0.13 per pound[3], respectively, were taken from Färe (2006). No reasoning was given for selection of that source or pollutants. These pollutants are standard for wastewater treatment and, thus, pollution control cost data is readily available, thereby lending to the use of the shadow pricing technique in this case. If these pollutants were not typically controlled and/or have data available to characterize control costs, then the external costs would need to be estimated by another means such as contingent valuation.

Key Findings and Notes: The 13 facilities were estimated to have mean annual and unit volume benefit of $5,240,000 per year ($1,022,000 without averted pollutant costs) and $56.5 ($9.5 without averted costs)

[3] Values presented were converted from Euros to Dollars (1.00 Euro = $1.35 values based on July, 2014 conversion rate) and from metric to US standard.

per ft^3 of reclaimed water, respectively. The mean overall averted costs (i.e., environmental benefit) came to \$48.4 per ft^3.

EcIA Case Study 2: Patel (2010) Strengthening the Business Case for Reuse.

Patel, A. (2010). ***Strengthening the business case for reuse.*** **http://www.lcmp.eng.cam.ac.uk/wp-content/uploads/W4-Strengthening-the-business-case-for-reuse.pdf** .

Material and Context: Steel reuse (without melting) for low-grade purposes in the United Kingdom.

Methods: LCCA.

Metrics: Direct and indirect costs.

How Methods and Metrics were Selected and Used to Make Decisions: No description was provided as to why specific methods and metrics were selected for use, although the title and repeated text centered on presenting the business case for reuse imply strict economic focus.

Limited direct cost-type parameters (e.g., costs of different life-cycle stages) were described based on a literature review of non-melting steel reuse. Costs were given as approximate per-tonne values for all of the following major steps in life cycle and with alternative disposal at landfill: primary production, fabrication, construction, de-construction, demolition, certification, and landfilling. The review captured data from four reports, primarily from Geyer and Jackson (2004), which collected "ballpark figures" from United Kingdom industry leaders and organizations, as well as the International Iron and Steel Institute.

Key Findings and Notes: Profit opportunities from stocking and reselling used steel in the U.K. were estimated to be \$187 per ton to \$711 per ton over the period October 2006 to June 2009, with an average of \$355 per ton[4].

3.3.3 SIA Studies

SIA Case Study 1: Preston (2013) Draft Environmental Impact Statement For The Disposal And Reuse Of The Former Naval Air Station Joint Reserve Base (NAS JRB) Willow Grove, Horsham, Pennsylvania.

Reference: Preston, G. (2013). ***Draft Environmental Impact Statement for the disposal and reuse of the Former Naval Air Station Joint Reserve Base (NAS JRB) Willow Grove, Horsham, Pennsylvania.*** http://www.horshamlibrary.org/%5CWillowGroveNASAdminRecord%5CPdfs%5CDRAFT-EIS-MAIN.pdf .

Material and Context: Land reuse of old naval base in Horsham, Pennsylvania.

Methods: EIS qualitative and quantitative analysis of land reuse alternatives' social (and economic) impacts.

Metrics: Land use patterns; presence of planning and zoning activity; population change; housing; change in community infrastructure, recreation, traffic, noise, cultural, historical, and archaeological resources and Native American tribes & indigenous peoples; employment, income (direct, indirect, short- and long-term); and other equity for minority groups.

How Methods and Metrics were Selected and Used to Make Decisions: The specific method selected follows a relatively recent EIS framework (compared to Rawls, 2001) given its set list of metrics, rigorous classification, and analysis of alternatives' (in)significant, beneficial or negative, and direct or indirect

[4] Values presented were converted from British Pounds to Dollars (1.71 £ = \$1.00 values based on July, 2014 conversion rate) and from metric to US standard.

impacts, and listing of mitigation measures as needed. Quantitative estimates were provided of social and economic impacts related to the following:

- local population increase;
- traffic, in terms of additional seconds of delay at key intersections, level of service (semi-quantitatively describes roadways' operating conditions based on speed, travel times and delay on a scale from A, "adequate", to F, "worst"), and number of external daily and peak AM/PM vehicle trips;
- noise in decibels, from construction (relative to maximum permitted sound pressure level), aircraft, and traffic (relative to noise abatement threshold permitted increase);
- housing, in terms of addition of new units;
- student enrollment increases (to observe potential to surpass capacity);
- local economic conditions, in terms of total construction expenditures made within the area;
- local jobs, both direct and indirect/induced; and
- tax revenue benefits for the township.

Key Findings and Notes: Alternatives were assessed with relatively in-depth analysis of impacts compared to other EISs reviewed.

SIA Case Study 2: Misheloff (2011) Integrated Water Resources Management II: Feasibility of Wastewater Reuse Report No. 14.

Reference: Misheloff, R. (2011). ***Integrated water resources management ii: feasibility of wastewater reuse report No. 14***. http://www.iwrm2eg.org/report/IWRMII/Report14Feasibility_of_WW_Reuse.pdf

Material and Context: Wastewater reuse for agriculture in pilot rural Egypt village.

Methods: Qualitative description of social processes and impacts, as assessed by (USAID.

Metrics: Cultural, historical, and archaeological resources; land use patterns; employment, income, and other equity for minority groups; identification of stakeholders; perceptions of risk; health and safety; distribution of power and authority; and community cohesion.

How Methods and Metrics were Selected and Used to Make Decisions: No direct explanation was given for why baseline data collection for the USAID Environmental Impact Assessment framework should cover social and economic metrics. Rather, the source listed the metrics in 10 bullet points, which makes this source representative of many of the "most-useful" SIA sources in terms of the presentation and limited depth of analysis. Additionally, no context was given for their listing of the wastewater pilot project examples of empowerment of communities and impacts such as improved gender relationships.

Key Findings and Notes: Only qualitative observations of the pilot were noted, such as increased community cohesiveness and lack of direct economic impact.

4. Discussion

In terms of the prevalence of EcIA and SIA methodologies, the distribution of those methodologies among the final group of 72 studies (i.e., the studies that gave information related to EcIA and/or SIA for beneficial reuse) came to 28 EcIA, 33 EcIA/SIA, and 11 SIA studies, (**Table 3**). The fact that SIA-focused studies were underrepresented illustrates how most reuse literature reviewed aims to demonstrate the profitability or other economic benefits of establishing reuse material processing operations (e.g., wastewater treatment facilities or the associated sale of biosolids for composting or agricultural amendment). Additionally, the fact that 7 of the 11 SIA studies that focused on reuse materials (rather than "waste disposal" options) only studied biosolids (4 studies) and wastewater (3 studies) further emphasizes how the field of research for them is much more mature than that for the other materials, which typically only included SIA or social metrics in passing (or with bulleted or paragraph description) when describing EcIA. The focus on wastewater and biosolids is likely due to negative public perceptions and attitudes about wastewater and biosolids reuse. C&D waste (6 studies) and tire (3 studies) reuse represent the next most-studied reuse materials. Their relative importance is also reflected by their inclusion in 3 of the 12 EcIA and SIA case studies. Due to increasing global awareness and demand for reduction and reuse of valuable waste products, materials reuse will likely rise as research and pilot initiatives become more innovative and explore reusing wastes outside of wastewater and biosolids, as opposed to the common disposal norms for these materials, such as landfilling.

4.1 Key Economic Methods, Metrics, Data and Examples

Most studies used basic or advanced CBA, while many supplemented that with a LCCA approach, generally looking at operation and maintenance costs. In addition to looking at costs and benefits, usually in the form of facility- or project-specific direct costs and revenues, a majority of studies also used "study-specific economic methods" to address indirect and external costs and economic impacts. These study-specific methods often entailed listing indirect and external costs (such as "impacts on local industries" or "effects on worker skills") and/or describing them qualitatively.

Table 5 shows that direct costs (e.g., revenue, facility costs) and direct employment (often classified as jobs) were the most-cited metrics (within 51 and 22 studies, respectively). Other aspects of employment (indirect, short-term, long-term, and local), effects on local industries, and effects on worker skills were cited in 18, 17, and 6 sources, respectively. This emphasizes the focus on costs and development of jobs and local economies, implying that the major purpose of many of the studies was to demonstrate the overall economic appeal of the reuse projects, as policy-makers, the general public, and other stakeholders frequently consider only those impacts.

This implication is further highlighted in many of the key statements of the EcIA and SIA case studies shown in **Section 3. 3**, which present a wide range of materials, logical or modeling frameworks, and levels of analysis of social impacts. Examples of the major points from the abstract, summary, or conclusion sections from four case-study sources include the following:

- "The net benefit of reusing and recycling of [C&D] waste materials is estimated at 2.5% of the total project budget [at the Malaysian site]" (Begum et al., 2006)
- "The life-cycle cost analysis completed…determined that RCA [recycled concrete aggregate] was both economically sustainable and feasible for application as a base material in highway construction [compared to virgin limestone aggregate]" (Donalson et al., 2010)
- "If the external benefit [shadow pollutant costs] of these projects is also incorporated, the economic feasibility analysis provided positive results for all water-reuse projects in the current study" (Molinos-Senante et al., 2011)
- "The [European Union Water Framework Directive] policy is to achieve Full Cost Recovery account[ing for] the environmental and resource costs associated with damage or negative

impact on the aquatic environment" (Mediterranean Wastewater Reuse Working Group, 2007).

The finding that the case studies strive to emphasize the cost-effectiveness (often with quantifying environmental externalities) of reuse is further bolstered by considering the representativeness of the studies. Given their wide range of materials—C&D waste in general, C&D waste as concrete, steel, and wastewater—and their geographic scope, it is clear that this desire to demonstrate cost-effectiveness is consistent throughout the literature. This representativeness is further illustrated by the case studies' range of logical and modeling frameworks, which include simplified CBA, LCCA (with and without valuation of indirect costs and/or external economic impacts), a literature review listing of key costs, and MCE with CBA and hedonic valuation.

Deeper analysis of the case studies revealed several potential trends that could inform policy-making for supporting beneficial reuse. Begum et al. (2006), Donalson et al. (2010), and the Mediterranean Wastewater Reuse Working Group (2007) all discussed the usage of, or directly use standard CBA and/or LCCA for either one specific site or an entire region without specifics. Also, the studies focused primarily on quantifying economic impacts, while only limited attempts to quantify or qualify social impacts were made, as seen in the following:

- Begum et al. (2006) mentioned but did not attempt to quantify the social (or environmental) benefits
- Donalson et al. (2010) only referred to social impacts as those related to the public health risks from road base leaching
- The Mediterranean Wastewater Reuse Working Group (2007) provided only qualitative descriptions for social impacts.

These and other authors should be encouraged to go beyond using "a conservative [economic analysis-only] method of estimation… [even if it is just] an initial study" (Begum et al., 2006) and take the next step towards more comprehensive methodologies, such as the following:

- Molinos-Senante et al. (2011), which used hedonic valuation to quantify averted pollution costs
- Sa-nguanduan and Nititvattanan (2011) which used the social impacts-inclusive methodology, whose economic-focused MCDA-type modeling also included semi-quantitative measures of public acceptance, as well as environmental externalities.

Additionally, using a literature review approach to inform potential economic and social impacts appears to be limited in value, as most studies rely on simplified CBA or LCCA (e.g., Patel, 2010). Relying instead on proactive survey methodology of all stakeholder groups and clear modeling logic, as laid out in Sa-nguanduan and Nititvattanan (2011), researchers will be better equipped in the future to develop more holistic analyses and better estimates of the benefits of waste material reuse, as well as present them to a wide audience.

4.2 Key Social Methods, Metrics, and Data and Examples

A high majority of SIA-focused sources utilized study-specific social methods, usually entailing a listing or qualitative description of social metrics. Many sources also incorporated stakeholder surveys to some extent, and a few used interactive community forum or social LCA methods. **Table 6** shows that the distribution of social metrics cited was more even than that of economic metrics. The breakdown of the most-cited metrics—attitudes towards policy/project (18 studies), perceptions of risk, health, and safety (16 studies), odor (15 studies), noise (14 studies), employment/income/other equity for minorities (11 studies), land use patterns and traffic (10 studies each)—illustrates the focus on overall "public

acceptance" and community resources concerns, such as citizens' adverse reactions to the physical stimuli arising from many human waste-reuse projects (e.g., the odor, noise and traffic associated with wastewater or biosolids treatment facility operations and transportation of products). These metrics are grouped and defined in this report as "acceptance and nuisance metrics."

In contrast, less focus was put on "other social metrics" (the grouping definition for the non-acceptance and nuisance measures) related to community/institutional structures or family/community networks, as well as "social well-being" and other more emotion-related impacts. The limited focus on other social metrics could be explained by how they are difficult to quantify, both in terms of quantitative format and methodology. Understanding how community structures and networks, as well as "social well-being," are impacted by beneficial reuse is crucial, but difficult and time- and resource-intensive to research in terms of survey development and execution or other methods. This complexity and required level of effort may explain why most of the SIA studies chose instead to assess the general "social acceptance" of a project and the common EIS-framework odor/noise/traffic/scenery impacts, which can often be quantified in terms of decibels or number of trips, or qualified in terms of significance as per EIS methodology.

Regarding common EIS-assessed impacts, the Preston (2013) EIS case study of land reuse suggested potential strategies for evaluating the hypothetical social impacts of alternative scenarios. It quantified impacts related to population increase, traffic trips (in kilometers traveled), and noise (in decibels), as well as analyzed a whole host of other social metrics that were mostly ignored through the remaining literature, such as impacts on Native American tribes and indigenous peoples and on cultural, historical, and archaeological resources. It also included estimates of economic, employment, and tax revenue benefits. The Preston study example highlights the current desire to move beyond the traditional EIS method to a more holistic and comprehensive approach, where a broader range of economic and social impacts are incorporated into environmental decision-making.

Quantified community-level impacts, and the ways through which they were quantified, present insight into the methods used for analyzing beneficial reuse decisions. Other modeling and decision analysis frameworks, such as the MCE–based analysis (of C&D waste reuse) executed in Craighill and Powell (2000)) gave quantitative assessment, but generally through subjective judgment of social-type data for the purposes of incorporating it into their LCAs. Using "low-medium-high" ranking (in Craighill and Powell, 2000) helped the authors derive interesting conclusions (e.g., pure landfilling, or reuse, of C&D waste was better than a mix of end-of-life processing in reducing many negative social impacts. Using LCA data within MCE driven by subjective weighting of social impacts (Craighill and Powell, 2000) and borrowing social indicators from the UNEP (2009) framework suggests a useful strategy for semi-quantitative SIA that are potentially adaptable for assessing other beneficial-reuse scenarios.

The utility of canvassing stakeholders was also displayed in Youngqist & Goldberger (2013). While they did not execute as much extensive stakeholder data collection as done with Padilla et al. (2013), their large survey represents a promising and standardized methodology for best gauging impacts related to public acceptance and the nature of related community impacts outside of the major nuisance social impacts.

However, as their case questions were not specifically directed towards the "other social metrics" assessed in this report, there is limited direct applicability of their methods and metrics. This is also true to some extent for Goldstein and Beecher's (2007) review of the social and other impacts of biosolids reuse and Misheloff's (2011) SIA of wastewater reuse. In using the most common methods within "study-specific social methods," which are qualitative listing and/or description of social metrics, both sources did not present frameworks or concrete information useful for decision-making. While the four social theme-focused paragraphs with 1–3 sentences each in Goldstein and Beecher (2007) and the 10 bullet points in Misheloff's overview of USAID SIA of wastewater reuse projects gave background of metrics

that should be considered, stronger frameworks with semi- or fully-quantitative metrics are needed to give policy-makers the evidence needed to better promote beneficial reuse.

The rationale for selecting and using specific method(s) is not explicitly described in the most of the literature, but is likely based on the goals of the project, cost of implementing the methods, availability of data, and other factors (e.g., familiarity of researchers with different methods or tools). Regardless of the exact methods and metrics used across the studies, they all provide the value of making the broader range of economic and social impacts more visible to decision-makers and key stakeholders and more integral to the decision-making process.

4.3 Data Gaps and Research Needs

Of the identified sources that provided more targeted information related to EcIA and/or SIA for material reuse, mostly for reuse of wastewater, biosolids and C&D waste, SIA-focused studies were relatively few in number compared to EcIA- and joint ECIA SIA-focused studies. While most EcIA sources used basic or advanced CBA (often with a LCCA approach) to analyze direct costs and overall employment impacts, most SIA sources utilized qualitative listing or short description of social metrics to overview general or hypothesized public attitudes towards policy/project, perceptions of risk, health, and safety, and type and impact of potential nuisances (e.g., odor, noise and traffic).

Key data gaps found, and potential research needs, are as follows:

1. Metrics and data for EcIA and SIA were usually presented in the context of impacts that can be directly attributed to a specific facility or project, rather than more comprehensive EcIA and SIA, which takes a broader view of internal and external impacts. This may be related to the primary need (and subsequent focus) for demonstrating the economic feasibility for material reuse, with secondary consideration given to externality costs and social impacts. Data were found to be generally lacking for characterizing non-market economic impacts and social impacts outside of public acceptance and nuisance metrics, which are difficult to quantify and thus appear infrequently in the literature. Research to fill these gaps, by developing adapted standardized methodologies for semi- or fully-quantitative assessment of non-market economic and social impacts, could involve exploring how the EIS framework can be modified and how MCE modeling and various software and approaches used in the literature can be tailored for specific reuse scenarios.
2. Another key gap is that while the beneficial reuse–related EcIA literature gave many examples of useful data for evaluating the benefits of reuse, most of it was facility and financial data rather than information on other economic impacts, such as jobs created (both spatially and temporally), tax revenue, and property value changes. Moving away from the facility-only mindset and utilizing methods that look at those more holistic economic impacts will help fill these data gaps and give policymakers more relevant information for advocating for beneficial reuse to local politicians, communities, and other stakeholders besides facilities managers.
3. Gaps in data for all of the SIA categories and metrics included in this report (and largely taken from NOAA) exist and are particularly acute for the non-acceptance and nuisance metrics. While some data for impacts not within that category, such as for number of traffic trips or miles driven and malodorous air and noise produced, have been quantified in EIS or MCDA literature, it was insufficient for the purposes of meta-analysis and discerning correlations among reuse scenarios and impact levels.
4. There is a general lack of approaches for identifying potential economic and social impacts up-front in an analysis. In general, studies and sources reviewed simply start with a list of impacts that are perceived to be important, or are important to stakeholders, and then try to

characterize those impacts. Studies that relied on the use of interactive community forum and EIS were the exception.

This lack of quantitative SIA-related data, as well as the scarcity of EcIA data beyond direct internal costs and revenue, could be remedied by adapting the quantification methodologies within the case studies highlighted above that attempted to quantify such data (e.g., the Preston [2013] EIS or Craighill and Powell [2000] LCA). Additionally, at a higher level, research needs to be conducted to adapt the rigorous EIS assessment protocol, as well as the MCDA-related modeling executed in Craighill and Powell (2000) and Sa-nguanduan and Nititvattanan (2011), both of which developed inventory scoring for social impacts and incorporated economic data besides direct costs. These two sources in particular could be studied in greater depth to discern how to utilize their software and/or modeling processes and decisions to best create platforms for assessing other reuse scenarios for which other metrics may be more relevant.

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Appendix A:
Selected Case Study Examples of Economic and Social Impact Assessment of Beneficial Reuse

Tables A-1 and A-2 list and summarize case studies covering EcIA and SIA (respectively) methods and metrics found in the literature that were specific to beneficial reuse topics. The studies discussed in the body of the report were selected as those that best illustrate the use of the economic and social methods most commonly used.

Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Waste Resources Action Programme (WRAP), 2011, miscellaneous (various consumer goods)	Life cycle cost-benefit analysis of various materials' reuse in the United Kingdom	Direct costs; employment; impacts on local industries	LCA scope, functional unit, and other features described in supplementary document, but no explanation for why LCA was selected; Excel tool takes user input for material, average lifetime of 2nd use, disposal route, product displacement type, and other information, and gives environmental, job creation and cost-benefit outputs to stakeholders	Total net costs and benefits to: local authorities, reuse organizations, and participating households and businesses	Annual monetary benefits and full-time jobs created were calculated for various clothing, furniture, and electronic goods
Begum et al., 2006, Construction and Demolition (C&D) waste	Cost-benefit analysis (CBA) for reuse and recycling at one project site in Malaysia; surveys of industry leaders for basic cost data	Direct and indirect costs; (SOCIAL) noise; odor; worker safety	Chose CBA as "standard measure of profitability;" did not attempt to quantify "intangible" benefits vs. costs (public image, environmental concern, etc. versus workers' health risk, noise and odor); used "a conservative method of estimation as it is an initial study"	Benefits included purchasing cost savings, re-sale revenue, waste collection cost savings, and landfill charge savings; costs included those for collection and separation, equipment purchase, storage and transportation	C&D reuse and recycling found to be profitable, with net benefits equivalent to 2.5% of the total project budget

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Donalson et al., 2010, C&D (concrete)	LCCA of aggregate options for roadbase in Winter Haven, Florida	Direct costs	No description of why they were selected; cost analysis method taken from Recycled Materials Resource Center, analyzing basic (delivery), installation and maintenance costs; literature review used to compile impacts (social ones interpreted as just related to leaching)	Material acquisition versus installation costs	Recycled concrete aggregate found to be more cost-effective than virgin limestone aggregate
John Ward, Inc., 2010, coal combustion products (CCP)	Selective benefit analysis of potential CCP use in US	Direct and indirect costs	Selected due to basis in literature review rather than novel research; used 2005 American Coal Council (ACC) Economic Assessment framework to estimate sales revenue; avoided disposal costs calculated with approach given in Electric Power Research Institute (Ladwig, 2010) report; building materials savings figures also attributed to EPRI report, which used Social Carbon Cost (US Department of Energy, 2010)	Ranges of benefits for CCP sales (to utilities, marketers and transporters), avoided on-site or landfill costs, and building material savings	ACC consultant report estimates annual benefits to be $6.4-11.4 billion USD, mostly as savings from use as sustainable buildings materials

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Kruglak, 2013, Flue Gas Desulfurization Gypsum	Selective benefit analysis based on Indiana farming data	Direct and indirect costs; employment	No description of why they were selected; industry-led research comparing financial data from one case study with that of typical farming program	Estimates of value of improved crop yield and fertilizer savings	Improved crop yield by $162/acre, and saved $51/acre of input fertilizer costs
Patel, 2010, steel	LCCA based on United Kingdom literature	Direct and indirect costs	No description of why they were selected; literature review of non-melting steel reuse captured data from 4 reports, primarily from one at right, which was sourced from United Kingdom industry/other leaders	Approximate cost per ton values for all major steps	"Ballpark figures" pulled from Geyer and Jackson, 2004
Simões et al., 2012, high-density polyethylene (HDPE) plastic	LCCA; hedonic valuation	Direct and indirect costs	Likely selected because they were used in Simões 2010; internal (direct) cost data for both AGL and virgin HDPE (production, distribution and end of life treatment) taken from Simões 2010's life-cycle inventory (LCI); external Carbon price from European Union Emissions Trading Scheme; external pollutant (damage) costs taken from Watkins and Holland (2000)	Costs for typical LCA stages along with CO2e, SO_2, NO_x and $PM_{2.5}$ emissions	Reuse of HDPE in Anti-Glare Lamellae (AGL) road safety product

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Albrecht et al., 2011, beverage containers	PriceWaterHouseCoopers-led industry surveys and review of open literature for analysis of deposit systems in Germany	Direct costs; employment; effects on local industries; cost-sharing; start-up difficulties, industry and government resistance or bureaucracy	"An assessment was made as to which costs arise from participation in the system for the individual stakeholders, in particular beverage producers and retailers, and the revenues that can be generated," in order to determine quantitative metrics; "in addition, [qualitative] impact categories [metrics] were identified that describe the effects of beverage packaging collection and recycling systems on the market situation and market dynamics"	Five-tier ranking system for ecological, social, and economic factors, based on quantitative and qualitative assessment	Assessed processing of plastic beverage containers for refillable deposit, one-way deposit, and dual systems; the refillable deposit system ranked best for all parameters, except for revenue

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Molinos-Senante et al., 2011, wastewater	Life-cycle cost-benefit analysis of 13 wastewater reuse projects in Spain; hedonic valuation	Direct costs; costs of pollution treatment	Selected cost metrics due to stated need to use conventional methodology, e.g., CBA; usage of hedonic valuation of pollutants justified as "the quantification of shadow prices…provides an alternative method for the valuation of externalities;" While shadow prices for suspended solids, Nitrogen, Phosphorus and chemical oxygen demand (COD) pollution were taken from Färe (2006), no reasoning was given for selection of that source or pollutants	Basic facility and financial costs combined with averted pollution costs	The facilities had mean annual and unit volume benefit of 3.9 million Euros per year (760,000 without averted pollutant costs) and 1.2 Euros (0.2) per m^3, respectively
Listowski et al., 2013, wastewater	Life-cycle CBA for wastewater reuse treatment facility in Australia	Direct costs	Cost metrics profiled in Economic Productivity model, CBA model with discounted cash flow analysis (chosen because it is "the primary tool for economic efficiency"), with focus on Avoided Costs equation and Reliability index	Basic facility and financial costs and revenue	Profit of $0.05 Aust. Dollars per m^3

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Hernández, 2006, wastewater	Life-cycle CBA, and qualitative description of externalities, for generic treatment facility	Direct costs; property value; cost of pollution treatment; (SOCIAL) noise; odor; interested and affected publics	"When calculating the total benefit, it is worth including internal benefit, benefits from externalities and opportunity cost," where net benefits for each one are revenue minus cost, detailed mostly for internal benefit; social and other externalities were not qualified or quantified	Basic and facility component costs given as a function of capacity	Equations for water unit cost for 8 treatment types based on capacity
Mediterranean Wastewater Reuse Working Group, 2007, wastewater	LCCA of wastewater reuse in Mediterranean context	Direct costs; employment; (SOCIAL) identification of stakeholders; concerns about social well-being; recreation; attitudes towards policy/project	Method chosen because it "is a useful way to evaluate the conditions under which treated wastewater reuse can be cost-effective and in comparing cost performances;" social and health risks and benefits described without context in 7 bullet points	Basic costs given as a function of capacity and end-use quality/other requirements	Advanced treatment for agriculture, livestock, industry and landscaping use gives full annual costs of 0.16 to 0.59 Euros per m^3 (for 40,000 to 4,000 m^3 per day flow, respectively) (Asano, 1998); European and US case studies given

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Table A-1. Beneficial Reuse-Specific EcIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Sanguanduan and Nititvattanan, 2011, wastewater	Contingent valuation; surveys of 33 utility staff and 200 households; multi-criteria evaluation; for 6 reuse alternatives in Thailand city	Direct costs; willingness-to-pay; (SOCIAL) attitudes towards policy/project and perceptions of risk, health and safety	"Specific data included importance order of criteria (5-rating scale), driving factors (rank), participation level (dichotomous), public acceptance (5-rating scale), and environmental economic values of reuse (dichotomous)" in order to "create a decision making system (DMS) incorporating multiple criteria, available alternatives, and environmental externalities focused on reuse"	Total utility, based on surveyed values (usually -1 to 1) and assigned criteria weights (within 4 models), of alternative scored from 0-100	Users had willingness to pay of 31% of tap water price; industrial reuse surprisingly rated higher than landscaping reuse
Winpenny, 2010, wastewater	CBA and cost-effective analysis (CEA) of 2 Spanish planned reuse schemes	Direct and indirect costs; effects on local industries; (SOCIAL) identification of stakeholders and attitudes towards policy/project	"Most kinds of economic appraisal use a *cost-benefit* framework;" the typical "data… should be [analyzed] in the following sequence, depending on whether CBA or CEA is chosen" and justifying the project by showing positive NPV or BCR or choosing the one with the lowest total discounted cost, respectively; the authors also define when "CEA is appropriate"	Basic facility and conveyance costs; new net benefits to agriculture (increased sales and savings) and value of water exchanged for city use (based on tariffs)	NPV-based Benefit to Cost Ratios as high as 2.85–5.35; highly sensitive to conservative valuation of urban water benefits; useful baseline information template given on page 93

Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Youngqist & Goldberger, 2013, biosolids	Mail survey of 1,374 households in Skagit County, WA	Odor; attitudes towards policy/project; concerns about social well-being; perceptions of risk, health, and safety; (ECONOMIC) effects on local industries	Survey questions (related to metrics) were chosen to better understand "residents' attitudes, opinions, and knowledge about the use of "Class A" biosolids…and to explore potential correlations between attitudes about biosolids and the demographics and lifestyle choices of respondents"	Mean scoring of pre-listed concerns, scaled 1-5	Residents were more concerned about public and environmental health than loss of property value and odor
Soh & Lang, 2011, biosolids	Analytical Hierarchy Process (AHP) and Simple Multi-Attribute Rating Technique methods within decision-tree weighting-based software model	Odor; scenery; traffic; noise; perceptions of health, risk and safety	Methods and metrics chosen due to "the need to adopt a structured approach…and use [the] decision software tool Criterium® DecisionPlus®, (InfoHarvest)…to perform a Triple Bottom Line (TBL) assessment of options;" metric selection explained as "a typical TBL analysis for biosolids management may include the [below] subcriteria (metrics)"	Percent alternative is likely to be best option; contribution of criteria to final score	Triple-bottom line analysis calculating "which option best meets the criteria, and how likely that alternative is to be truly the best choice"

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Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Goldstein and Beecher, 2007, biosolids	Summary of factors classified as" risk perceptions, outrage factors, risk communication and public participation, and earning [public] trust"	Perceptions of health, risk and safety; odor; traffic; trust in political and social institutions; identification of stakeholders; interested and affected publics; attitudes towards policy/project	No description of why they were selected; qualitative description in paragraphs of those metric-inclusive themes (arising from Beecher, 2004), of 1-3 sentences each	None	Qualitative description only of biosolids management concerns
Rawls, 2001, biosolids	Environmental Impact Statement (EIS) qualitative analysis for Spokane, WA wastewater treatment facility project	Land use patterns; odor; attitudes towards policy/project; noise; traffic	Follows relatively old EIS framework with set list of metrics and rigorous analysis of overall laws and guidelines, impacts of alternatives during construction and operation, and mitigation measures	None	Analysis of 6 types of biosolids management strategies

Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Craighill & Powell, 2000, C&D waste	Life-Cycle Full Cost Accounting and Life Cycle Impact Assessment of landfilling and/or reuse and/or recycling scenarios in the United Kingdom; contingent and other valuation of externalities; multi-criteria evaluation sensitivity modeling	Perceptions of health, risk and safety; land use patterns; scenery; noise; traffic; odor; (ECONOMIC) direct and indirect costs; employment	For developing LCI, externality-type impacts "were measured on a qualitative scale [of low, medium or high], based on the researchers' subjective judgment;" literature review and expert/industry consultation were used for valuing externalities and financial costs (especially for quantified typical financial costs); this was combined with subjective weighting of social impacts (e.g., jobs, noise and traffic, scenery, and odor, listed in order of descending weight) within the sensitivity-analysis performed with HIVIEW software	Per tonne of C&D waste, quantitative life-cycle impact analysis (LCIA) results given for traffic (in km), malodorous air (in m^3), jobs (person-days), and land use, scenery (visual), and noise impacts, all of which scored between 8-14	Landfilling or reuse generally rated better in land use, visual and noise impacts than combination of options; reuse rated best for odor, minimized external cost, and every component of triple bottom line, but worst for job creation

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Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Preston, 2013, land reuse	EIS qualitative and quantitative analysis of land reuse alternatives' social (and economic) impacts for old naval base in Horsham, PA	Land use patterns; presence of planning & zoning activity; population change; housing; change in community infrastructure; recreation; traffic; noise; cultural, historical, and archaeological resources; Native American tribes & indigenous peoples; (ECONOMIC) employment; income (direct, indirect, short- and long-term); other equity for minority groups	Follows relatively new EIS framework with set list of metrics, rigorous classification and analysis of alternatives' (in)significant, beneficial or negative, and direct or indirect impacts, and listing of mitigation measures as needed	Quantified impacts related to population increase, traffic trips, and noise (in decibels), as well as economic, jobs and tax revenue benefits	Assessed alternatives with relatively in-depth analysis of impacts compared to typical EIS

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Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Dehghanian & Mansour, 2009, tires	AHP modeling of Iran tire reuse end-of-life options (mechanical and cryogenic pulverization, and incineration in cement kiln)	Worker safety; perceptions of risk, health, and safety; (ECONOMIC) direct costs; employment; effects on local industries	AHP modeling chosen in order to present optimization tool for balancing out triple bottom line components; consulting industry experts helped select "employment," "local development," "damage to worker" and "product [perceived] risk" as social criteria, in descending order of weight (relative importance); AHP software Expert Choice 2000 used, among others	Weights on social categories used in software to calculate Social Indicator score (0-300)	Due to high employment weighting for Social Indicator, "social objective is almost aligned with profit"
Poulter, 2007, wastewater	EIS-type qualitative determination of "Impact Category" (severity) of wastewater reuse-for-agriculture alternatives for Sonoma County, CA	Scenery; cultural, historical, and archaeological resources; employment, income, and other equity for minority groups; presence of planning and zoning activity; perceptions of risk, health, and safety; residential stability; noise; displacement and relocation concerns; change in access to water infrastructure; odor; worker safety; recreation; traffic	Slightly different organization of metrics and classification of impacts and mitigation measures than that in EIS by Preston (2013), due to how this is an Environmental Impact Report (EIR); less focus on land-type issues (e.g., ignores "indigenous peoples" metric) and more focus on odor and other concerns relevant to wastewater reuse	"Impact Category" ratings (e.g., "Significant but Mitigable") are related to "Threshold of Significance" for each parameter, which provides useful context in EIR for evaluating social impacts (City of San Diego Development Services, 2011)	Analysis of potential for alternatives to "physically divide a Community" and "to conflict with goals, objectives, and policies identified in Sonoma County General Plan" covers multiple social metrics

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Table A-2. Beneficial Reuse-Specific SIA Methods, Metrics and Data (continued)

Author, Year, Material	Methods and Context	Metrics	Other Notes on Methods and Metrics	Data	Other Notes
Misheloff, 2011, wastewater	Qualitative description of "social processes and impacts" assessed by United States Agency for International Development (USAID) in wastewater reuse for agriculture in Egypt	Cultural, historical, and archaeological resources; land use patterns; employment, income, and other equity for minority groups; identification of stakeholders; perceptions of risk, health, and safety; distribution of power and authority; community cohesion	Doesn't explain why "baseline data collection [for the USAID EIA framework] should cover the following [social and economic metrics]," but rather just lists them in 10 bullet points; the same is true for their listing of the wastewater pilot project "examples of social processes [e.g., empowerment of communities] and impacts [e.g. improved gender relationships]"	Only qualitative observations noted, such as "group [community] cohesiveness" and "no direct positive [economic] impact"	Framework for "USAID Social Impact Assessment of Using Treated Wastewater in Irrigation" applied for initial stages of Egyptian village pilot
Padilla et al., 2013, wastewater	Social LCA (UNEP) for Mexico wastewater reuse for agriculture, with LC Inventory data coming from literature review and expert and household surveys	Worker satisfaction and safety; odor; attitudes towards policy/project; distribution of power and authority; (ECONOMIC) employment/income characteristics	Based on selecting 23/31 wastewater reuse-relevant subcategories (metrics) from UNEP framework stakeholder groups; used subjective "intuitive rating scale, based on a four level scale for each subcategory"	1–4 rating of metrics	Rural wastewater reuse facility scored lower than urban one in terms of social benefits; equivalent worker advantages ratings

Appendix B:
Database Description

Section 2 of the report describes the process to identify documents with information on methods, metrics and data used to evaluate the social and economic impacts of BU scenarios. Consistent with this process, RTI also developed a database to house the document specific information and the initial results of the documents' review. The database contains information on all the documents, including those that were deemed "Not Useful" according to **Section 2.2.1 Evaluation Criteria Used to Select Useful Sources**. The documents can be sorted according to the review tier, Tier 1 (screening review using the documents' abstract or executive summary) and Tier 2 (final review of the full text for Tier 1 "Useful" and "Potentially Useful" documents). The following sections present more detailed description of the database.

B.1 Structure of Tables and Forms

All the information collected on the documents identified is stored in "tbl_data".

The "Data Entry" form links to "tbl_data" and it shows when you open the database. This form is being used to facilitate data entry.

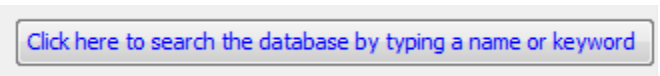
The "Data Entry" form is divided into three sections:

1. Basic information about the documents identified. This information is obtained in a tabular format when documents are identified using bibliographic databases. Otherwise, the information was manually populated, with the exception of the "ID" field, which is automatically generated by the DB (please note that there are instances where the "ID" is not sequential because this field does not get updated every time that a record is deleted).
2. Tier 1 Review are fields that were populated during the "Tier 1 Review" (see **Section 2.2.1**)
3. Tier 2 Review are fields that were populated during the "Tier 2 Review" (see **Section 2.2.1**). These fields were chosen to enable us answering questions such as, e.g., what type of information is presented in the studies (social and/or economic methods, metrics and/or data?), what type of material is being analyzed, is it a beneficial reuse material?
4. Number entries are provided for the "Methods" and "Metrics" fields for consistency on how the information is being recorded. Please note the meaning of the numbers can be found under the tables "lt_Methods" and "lt_Metrics".
5. Information on methods and metrics was only recorded for documents that made it to the "Tier 2 review" process (i.e., documents found to be "Useful" or "Potentially Useful" during the Tier 1 Review).
6. The QA/QC section is for RTI internal use, which is why most of the information in this section was removed from the final version of the database.

B.2 Navigations Functionalities

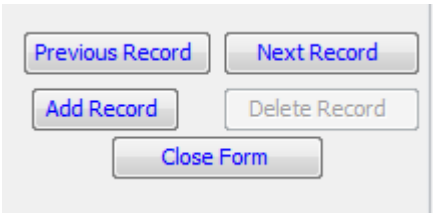
Searching within the "Data Entry" form can be performed using the following navigation tools:

- The universal search button shown below, which works the same as "ctrl+F" in Excel. The user has to click on a particular field first if s/he wants to "Look In: Current Field". "Match: Any Part of Field" has to be selected, otherwise will be looking for an exact match of the entire content of the field.



- The dropdown menu shown below. The information in the dropdown menu corresponds to the citation and it is not populated for documents where it would require manual entry.

- The buttons at the bottom of the "Data Entry" form (see below).



- The default search functions shown below.