Greening of the World of Work: Implications for O*NET®-SOC and New and Emerging Occupations

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Introduction

The purpose of the current research was to investigate the impact of green economy activities and technologies on occupational requirements in an effort to determine their impact on current O*NET®-SOC occupations and to identify new and emerging (N&E) occupations that may be considered for inclusion in the O*NET-SOC system. Toward this end, over 60 publications on various workplace topics relevant to the green economy were collected and reviewed. These publications included established academic journals, commissioned reports, industry white papers, and governmental technical reports. Additionally, numerous internet sources on the world of work were reviewed.

This report is organized in three sections. Section I describes the occupational implications of the green economy and its associated activities and technologies. Section II focuses on important occupational staffing implications within different sectors of the green economy. Section III describes the methodology and results of this research, including identification of current O*NET-SOC occupations impacted by the green economy and specific green economy N&E occupational candidates.

Occupational Implications of the Green Economy

The term "green," prevalent in our current national dialogue, is widely applied to a substantial variety of products, services, and even lifestyle or consumer choices. However, many of these applications are either not relevant or practical for occupational analysis or workforce development efforts. Moreover, existing definitions of "green job" are too molecular for occupational taxonomies such as the O*NET taxonomy and overlook the degree to which green economy activities differentially impact occupational requirements.

To ascertain the implications of the green economy for occupations, an important initial priority was to define the green economy.

> *The green economy encompasses the economic activity related to reducing the use of fossil fuels, decreasing pollution and greenhouse gas emissions, increasing the efficiency of energy usage, recycling materials, and developing and adopting renewable sources of energy.* [1, 2, 3, 4]

It was also important to establish conceptual and definitional boundaries for "green employment" or work in so-called "green jobs." The appropriate level of analysis for the current research was at the occupational level. In this report occupations are viewed as groupings of work roles that span multiple organizations but share common purposes

and common requirements of incumbents. [5] According to the U.S. Department of Labor, an occupation is defined as follows:

> *Group of jobs, found at more than one establishment, in which a common set of tasks are performed or are related in terms of similar objectives, methodologies, materials, products, worker actions, or worker characteristics.* [6]

Green economy activities and technologies may have different effects on different occupations. Accordingly, some experts have argued that it is essential to move beyond simply applying a broad label such as "green." [7] Thus, a more prudent approach is to focus on the "greening" of occupations, which is defined in this report as follows:

> *The "greening" of occupations refers to the extent to which green economy activities and technologies increase the demand for existing occupations, shape the work and worker requirements needed for occupational performance, or generate unique work and worker requirements.*

This definition lends itself to three general occupational categories, each describing the differential consequences of green economy activities and technologies on occupational performance.

> *Green Increased Demand Occupations*. The impact of green economy activities and technologies is an increase in the employment demand for an existing occupation. However, this impact does not entail significant changes in the work and worker requirements of the occupation. The work context may change, but the tasks themselves do not.
>
> *Green Enhanced Skills Occupations*. The impact of green economy activities and technologies results in a significant change to the work and worker requirements of an existing O*NET-SOC occupation. This impact may or may not result in an increase in employment demand for the occupation. The essential purposes of the occupation remain the same, but tasks, skills, knowledge, and external elements, such as credentials, have been altered.
>
> *Green New and Emerging (N&E) Occupations*. The impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements, which results in the generation of a new occupation relative to the O*NET taxonomy. This new occupation could be entirely novel or "born" from an existing occupation.

With definitions of green economy, occupation, and the greening of occupations established, the next step was a finer-grained examination of the broader green economy. After reviewing existing lists of major green economy sectors, 12 sectors were chosen based on those areas typically discussed in the extant literature.

- *Renewable Energy Generation*
- *Energy Efficiency*
- *Energy Trading*
- *Research, Design, and Consulting*
- *Agriculture and Forestry*
- *Recycling and Waste Reduction*
- *Transportation*
- *Green Construction*
- *Energy and Carbon Capture*
- *Environment Protection*
- *Manufacturing*
- *Governmental and Regulatory*

Each of these 12 green sectors was researched to ascertain general sector activities, recent trends, and workforce implications (see Section II). More specifically, emphasis was placed upon determining the levels of occupational greening within these sectors.

Green Economy Occupations and Candidate O*NET N&E Occupations

Green occupations identified in this report come from three different sources: (a) occupations included in the 2006 O*NET-SOC taxonomy, [8] (b) N&E occupations identified from research conducted on in-demand industry clusters, [9] and (c) N&E occupations identified during the current research on the greening of the world of work.

Existing O*NET-SOC occupations in the 2006 taxonomy impacted by the green economy can be classified as “green increased demand” or “green enhanced skills” occupations. Green increased demand occupations include existing O*NET-SOC occupations experiencing an increase in employment demand, but not significant changes in the work or worker requirements. Green enhanced skills occupations include existing O*NET-SOC occupations for which the essential purpose has not changed, but tasks, skills, knowledge, and other such elements have been altered by green economy activities and technologies.

In relation to the O*NET system, N&E occupations, both from previous and current research efforts, are defined as (a) occupations that involve work significantly different from that performed by incumbents of other occupations and (b) are not adequately reflected by the existing O*NET system. Candidate N&E occupations that do not perform work significantly different from the work of existing O*NET occupations are not considered N&E occupations. [10]

Within the context of occupations impacted by the green economy, this definition of N&E occupations defines “green new and emerging (N&E)” occupations. That is, N&E “green” candidates are occupations for which the *impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements, resulting in the generation of a new occupation*.

Through a multi-stage research and screening process (see Section III),

- 64 O*NET-SOC occupations were found to qualify as “green increased demand” occupations,
- 60 O*NET-SOC occupations were found to qualify as “green enhanced skills” occupations,
- 45 O*NET-SOC N&E occupations previously identified through research on in-demand industry clusters were found to qualify as “green N&E” occupations, and
- 46 candidate N&E occupations in the green economy were found to qualify as “green N&E” occupations.

These occupations are presented, by sector, in Appendices A-C of this report. Appendices D-F provide a listing of all green O*NET-SOC occupations, organized by occupational category (green increased demand, green enhanced skills, and green N&E).

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SECTION I: OCCUPATIONAL IMPLICATIONS OF THE GREEN ECONOMY

Section I-1: Overview of the Green Economy

It is certainly no exaggeration to note that the label "green" has become ubiquitous. Underlying this prevalence is a substantial body of literature focused on all things green. This literature spans multiple disciplines (e.g., labor economics, engineering, environmental science) and is found in a variety of outlets ranging from the popular press to governmental reports to academic journals. The overall conclusion from this burgeoning domain is that the "greening" of our national economy is not only currently underway, but also that it should be met with concerted efforts to significantly increase both intellectual and financial capital investments. Numerous arguments for such amplified attention are frequently proffered to include issues of national security, environmental protection, climate change, and domestic job growth.

Enabling focused investment requires systematic study to better understand and define what it means to be "green." The rush to jump on the "green" bandwagon has outpaced the development of a concept of what it actually means to be green. For example, consider the praise by the popular press of individuals "going green" by using recycled goods and reducing consumption, or specific companies by increasing energy efficiency, or municipalities offering grants for green residential construction projects (e.g., fitting homes with solar panels). In other words, green activities can range from choosing a specific brand of cleaning spray to installing a wind energy farm. To determine the workforce ramifications of this vast array of green activities is a substantial undertaking. The first step is to focus the scope by developing a precise and bounded definition of what the green economy means in the context of jobs or occupations.

A thorough understanding of any job or occupation requires an understanding of the context in which these entities exist. One way to conceptualize the broader context of work is through an economic lens – in the present case, what is referred to as the green economy. Fortunately, there is a general consensus in the extant literature regarding the scope of the green economy, which is summarized in the definition below.

> *The green economy encompasses the economic activity related to reducing the use of fossil fuels, decreasing pollution and greenhouse gas emissions, increasing the efficiency of energy usage, recycling materials, and developing and adopting renewable sources of energy.* [1,2,3,4]

In support of these goals is a range of activities and strategies, including retrofitting buildings to improve energy efficiency, promoting usage of mass transit, producing energy-efficient automobiles, increasing the use of wind or solar power, and developing

and producing cellulosic biomass fuels. [5] The significant benefits of green economy activities are significant and described as both macroeconomic (e.g., investment in new technologies, greater productivity) and microeconomic (e.g., income growth, job growth). [6,7] For instance, analysts concluded that renewable energy and energy efficiency technologies generated over 8 million new jobs and $970 billion in revenue in 2006 alone. [8]

At the heart of green economy activities is technology. That is, technological innovations are what drive the many activities that comprise the green economy. For example, clean energy technologies use the sun, wind, water, and plant matter to produce electricity, heat, and transportation fuel. [9] New green technology also spans a broad range of products, services and processes that lower performance costs, reduce or eliminate negative ecological impact, and improve the productive and responsible use of natural resources. [10] Thus, understanding the development and application of various green technologies can help to depict the potential workforce implications of green economy activities.

With the broader context of the green economy now delineated, the following section turns attention toward describing how occupations are influenced by this context. In this section, existing definitions of green jobs are reviewed and critiqued in an effort to better establish descriptive boundaries that are of practical use for occupational analysis. Special emphasis is given to the technologies that facilitate or enable the green economy activities discussed above.

Section I-2: The "Greening" of Occupations

Although there is no commonly accepted definition of "green job," the existing literature does offer a variety of definitions. [11] Below are typical examples.

> "Green jobs are jobs in the primary industries of a green economy that promote environmental protection and energy independence." [12]
>
> [Green collar jobs are] "well-paid, career-track jobs that contribute directly to preserving or enhancing environmental quality." [13]
>
> "A green collar job is a paid position providing environmentally friendly products or services." [14]
>
> "[Jobs associated with] any activity that generates electricity using renewable or nuclear fuels, agriculture jobs supplying corn or soy for transportation fuel, manufacturing jobs producing goods used in renewable power generation, equipment dealers and wholesalers specializing in renewable energy or energy-efficiency products, construction and installation of energy and pollution

management systems, government administration of environmental programs, and supporting jobs in the engineering, legal, research and consulting fields." [15]

For occupational analysis, the definition for a green occupation must focus on what it means to be an occupation and what effects the green economy has (or may have) on occupations. Thus, what is needed is a data reduction approach in defining green jobs or occupations to increase the parsimony and precision of green definitions. [16] Key to accomplishing this task is establishing clear boundary conditions and distinct levels of specificity for any proffered definition.

Occupations are groupings of work roles that span multiple organizations but share common purposes and common requirements of incumbents. [17] More specifically, an occupation can be viewed as a "group of jobs, found at more than one establishment, in which a common set of tasks are performed or are related in terms of similar objectives, methodologies, materials, products, worker actions, or worker characteristics." [18] In addition, an occupation is an entity that exists at a level "above" individual incumbents or positions within an organization, in part because numerous individuals and related jobs reside within a particular occupation.

Defining occupations in this manner is important to the notion of "green jobs" in at least two ways. First, it clearly signals the need to shift the level of specificity from "job" to "occupation" when discussing the workforce implications of the green economy. The current literature focuses almost exclusively on green jobs – or simply green job titles - rather than taking a perspective more conducive to workforce development efforts: an occupational perspective. Second, defining occupations in this way places an emphasis on the various work and worker requirements (e.g., tasks, skills, knowledge) requisite to occupational performance. Because many green technologies are still at the development stage and workforce results of the application of these technologies are not yet clear, the extant green economy literature has not taken an occupational-level approach, focusing instead on broader industry-level outputs or products, such as renewable power generation and environmental protection enhancement. This broader focus provides very little information regarding specific green-driven changes in the way individuals work or, the requirements of individuals performing this work.

There is an additional dimension to be accounted for in determining the impact of the green economy on occupations: determining the extent to which green economy effects are (a) creating entirely new occupations, (b) significantly changing the work or worker requirements of existing occupations, or (c) simply increasing the demand for workers in existing occupations. These distinctions are essential for locating, describing, and forecasting potential workforce consequences of the green economy. In the interest of workforce development, it is important to consider how the occupation is either created by green economic activities or changing due to these activities when labeling the occupation as "green." In a recent report for the Texas Workforce Commission, Anderberg pointed out the importance of a systematic approach to describing the effects of the green economy on occupations.

> "Conferring the green label to entire constellations of occupations or to discrete tasks and work assignments does not necessarily imbue them with special skill requirements that must be addressed with some new education and training intervention. The skills needed to perform some green work assignments will be absolutely no different than those required to perform tasks and work assignments similar, if not identical, to their non-green predecessor. Other green work assignments may be so radically different than their predecessors that an entire degree- or certificate-granting program needs to be developed to impart the necessary knowledge, skills and abilities." [19]

To summarize, there are two primary implications for occupational analysis in general, and the O*NET system in particular. First, the vast job-level information in the existing green economy literature must be consolidated and interpreted for its meaning at the occupation level. In particular, a focus on occupational requirements (tasks, duties, tools and technology, knowledge, skills, and so forth) is essential for discovering the occupational implications of the green economy.

Second, any analytical or descriptive approach used to determine the occupational implications of the green economy must be sensitive to the varying degrees with which green economy activities shape occupational performance. This entails a definitional approach to "green occupations" that moves beyond labeling (i.e., green as adjective) to encompass the dynamic nature of occupational performance (i.e., greening as verb). A parallel can be seen in the shift away from an emphasis on "organization" to "organizing" in the general management literature in order to address the effects of contextual changes in the 1990s (e.g., flattening of firms, use of teams, project-based work). Thus, a valid approach to defining green occupations is to instead define the "greening of occupations."

> *The "greening" of occupations refers to the extent to which green economy activities and technologies increase the demand for existing occupations, shape the work and worker requirements needed for occupational performance, or generate unique work and worker requirements.*

This definition lends itself to three general categories, each describing the differential consequences of green economy activities and technologies on occupational performance. These categories of occupations are described below and include examples of the effects indicative of each. Note that the term "existing occupation" means it is already included within the O*NET database, whereas "new occupation" means it is not yet included in the database.

> *Green Increased Demand Occupations*. The impact of green economy activities and technologies is an increase in the employment demand for an existing occupation. However, this impact does not entail significant changes in the work and worker requirements of the occupation. *The work context may change, but the tasks*

themselves do not. An example is the increased demand for electrical power line installers and repairers related to energy efficiency and infrastructure upgrades. [20]

Green Enhanced Skills Occupations. The impact of green economy activities and technologies results in a significant change to the work and worker requirements of an existing occupation. This impact may or may not result in an increase in employment demand for the occupation. An example is the occupation architect, where greening has increased knowledge requirements pertaining to energy efficient materials and construction, as well as skills associated with integrating green technology into the aesthetic design of buildings. For example, many architects have pursued Leadership in Energy and Environmental Design (LEED) certifications to ensure the proper application of U.S. Green Building Council principles to building designs. The essential purposes of the occupation remain the same, but tasks, skills, knowledge, and external elements, such as credentials, have been altered.

New and Emerging (N&E) Green Occupations. The impact of green economy activities and technologies is sufficient to create the need for unique work and worker requirements, resulting in the generation of a new occupation. This new occupation could be entirely novel or "born" from an existing occupation. An example would be solar system technicians who must be able not only to install new technology, but also to determine how this technology can best be used on a specific site.

Given these definitions of occupational greening and the related impacts, the next section offers an integrative framework for describing the major green economy activities and their respective technologies. As aforementioned, a focus on green technology is beneficial for occupational analysis precisely because the use and development of such technology is proximal to occupational performance. Thus, understanding how green technology is applied toward various green economy activities can inform the potential impact of these technologies on occupational demands (e.g., employment needs, work and worker requirement changes).

Section I-3: Linking Green Economy Activities and Technology to Occupational Greening

As described previously, the major activities of the green economy include decreasing fossil fuel use and greenhouse gas emissions, increasing energy efficiency and recycling, and developing and adopting renewable energy sources. While useful for describing the general functions of the green economy at a broad level, more precise delineations are necessary for efficiently and effectively determining the potential occupational implications of green technology. A comprehensive review of the current literature reveals 12 distinct sectors of the green economy (presented below). [21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31] It is important to note that this list is not meant to be exhaustive, as the green economy is certainly dynamic, but these sectors were mentioned across multiple

sources suggesting a consensus of their importance. In addition, these sectors are by no means completely independent; rather, their goals and functions are often inextricably linked to one another. Nonetheless, the precise view of green economy activities that is afforded by these categories allows for a more thorough determination of potential occupational implications. These categories also ensure that occupational research spans the entire spectrum of green economy activities and technologies.

1. *Renewable Energy Generation*. This sector covers activities related to developing and using energy sources such as solar, wind, geothermal, and biomass. This sector also includes traditional, non-renewable sources of energy undergoing significant green technological changes (e.g., oil, coal, gas, and nuclear).

2. *Transportation*. This sector covers activities related to increasing efficiency and/or reducing environmental impact of various modes of transportation including trucking, mass transit, freight rail, and so forth.

3. *Energy Efficiency*. This sector covers activities related to increasing energy efficiency (broadly defined), making energy demand response more effective, constructing "smart grids," and so forth.

4. *Green Construction*. This sector covers activities related to constructing new green buildings, retrofitting residential and commercial buildings, and installing other green construction technology.

5. *Energy Trading*. This sector covers financial services related to buying and selling energy as an economic commodity, as well as carbon trading projects.

6. *Energy and Carbon Capture and Storage*. This sector covers activities related to capturing and storing energy and/or carbon emissions, as well as technologies related to power plants using the integrated gasification combined cycle (IGCC) technique.

7. *Research, Design, and Consulting Services*. This sector encompasses "indirect jobs" to the green economy which includes activities such as energy consulting or research and other related business services.

8. *Environment Protection*. This sector covers activities related to environmental remediation, climate change adaptation, and ensuring or enhancing air quality.

9. *Agriculture and Forestry*. This sector covers activities related to using natural pesticides, efficient land management or farming, and aquaculture.

10. *Manufacturing*. This sector covers activities related to industrial manufacturing of green technology as well as energy efficient manufacturing processes.

11. *Recycling and Waste Reduction*. This sector covers activities related to solid waste and wastewater management, treatment, and reduction, as well as processing recyclable materials.

12. *Governmental and Regulatory Administration*. This sector covers activities by public and private organizations associated with conservation and pollution prevention, regulation enforcement, and policy analysis and advocacy.

Section I-4: Section Summary

To summarize, the term “green” is widely applied to a substantial variety of products, services, and even lifestyle and consumer choices. Many of these applications are hard to apply to occupation analysis or difficult for use in workforce development efforts. Existing definitions of what comprises a “green job” are at a level of specificity that seems too molecular for occupational databases such as the O*NET database. Further, such definitions do not address the degree to which green economy activities differentially impact occupational requirements.

To address these issues, several definitions were presented. Considering the primary purpose of this report is to ascertain the implications of the green economy for existing and new and emerging O*NET occupations, definitions of the green economy and of the term occupation were presented. Next, a finer-grained definition that encompassed the impact of green economy activities and technologies on occupations was described. This definition focused on the “greening” of occupations and included three categories that represented varying degrees of influence that the green economy holds for occupational performance. Finally, to facilitate an examination of how specific occupational greening might occur, a list of 12 green economy sectors was introduced. Each of these sectors is described in more detail in the next section. These descriptions include brief synopses of major activities and associated green technologies, and specifically address any occupational implications associated with the sectors.

SECTION II: OCCUPATIONAL STAFFING IMPLICATIONS BY GREEN SECTORS

The 12 green sectors previously presented are described in this section. The primary purpose of these synopses is to provide snapshots of general sector activities, recent trends, and potential implications for occupations. This section therefore provides a backdrop to facilitate interpretations of subsequent report sections presenting specific categories of occupations that are impacted by occupational greening.

These sectors were derived from sectors identified in multiple reports within the existing literature. Some sectors are more specific than those often discussed in the literature. This increased specificity allows a more comprehensive depiction of the potential occupational implications of various green economy activities. It should be noted that these 12 sectors are not necessarily equal in terms of scope, economic activity, and occupational potential. Some are currently far more active than others. For example, estimates for California have shown roughly 74% of the total green economy is attributable to activities in renewable energy generation and energy efficiency. [32] Nevertheless, all have the potential to affect work and its context.

Section II-1: Renewable Energy Generation

This sector is arguably seeing the greatest development and growth within the green economy and is at the heart of most "green" discussions. Government regulations, energy costs, climate change, and the depletion of natural resources are all factors driving growth and change in this sector. As of 2008, 24 states and the District of Columbia have enacted regulations ("renewable portfolio standards") that require a particular portion of electricity to be generated from renewable sources. [33] Such renewable energy sources include wind, solar, geothermal, hydropower, biomass, and hydrogen. [34, 35, 36, 37, 38, 39] It has been estimated that total net renewable power generation will increase by 30%, which equates to 40% of total domestic power generation. [40] Each of these renewable sources is briefly described below. Also included in this sector are traditional, non-renewable sources of energy undergoing significant green technological changes, such as oil, gas, coal, and nuclear.

Wind

Energy derived from wind is commonly used for a variety of purposes such as generating electricity, charging batteries, pumping water, or grinding grain. [41] Wind is reportedly the fastest growing source of renewable energy, both in the U.S. and worldwide, and it has been estimated that potential wind energy resources exist in 46 of

the 50 states. During the past 5 years, wind facility installations have grown at a rate of just under 25% per year. [42]

Currently, wind provides only about .4% of energy consumed in the U.S. but its use is growing rapidly due to continual construction of new wind farms and recent breakthroughs in wind technology. In fact, it has been argued that state-of-the-art windmills of suitable scale for use by electric utilities could generate electricity at less than one-half the cost of gas-fired power. Examples of this new wind technology include 40-story turbines with blades spanning 200 feet, as well as offshore wind farms such as a 130-turbine installation in Nantucket Sound, Massachusetts. In addition, government tax incentives have also boosted the use of wind-driven equipment. [43]

Solar

Solar power is expected to show slow and steady growth as it creates greater interest among users such as metropolitan areas. [44] Currently, more than 850 American companies manufacture, install, and sell solar system components. The U.S. is regarded as the world leader in solar research and manufacturing. [45]

A critical component in the use of solar power is photovoltaic technology, which comprises the electricity-generating layers of silicon between solar panels. Until recently, this equipment has been considered too cost-prohibitive to compete with traditional power generation methods. However, recent research and capital investments are expected to enable solar power to be an economically competitive power source within the next ten years. [46, 47]

In addition to photovoltaic cells, solar power innovations include concentrating solar power (CSP) technologies and low temperature solar collectors. While photovoltaic cells convert sunlight directly into electricity, CSP or solar thermal technologies use reflective materials to increase the concentration of the sun's energy. CSP technologies utilize mirror-covered dishes that rotate throughout the day to track the sun and subsequently heat hydrogen to drive generator pistons that produce electricity. Such dishes are becoming more affordable and their use has been demonstrated in states such as California. [48, 49]

Geothermal

Energy from this renewable source is obtained from the heat of the Earth tapped at various depths ranging from shallow ground to hot water and rock a few miles below the ground, to deeply buried magma. Hot water or steam sources are typically used to supply steam turbines that, in turn, generate electricity. [50] Forecasts have estimated an 87% increase in geothermal energy production over the next two decades, which should result in approximately 35,000 new jobs in drilling, power plant construction, equipment supply and manufacturing, and operation and maintenance. [51]

Geothermal energy is recognized as very reliable and cost-effective. However, geothermal plants must be located in very specific areas, such as those with volcanic activity, tectonic plate shifting, or major hot springs and geysers. Technological innovation is available to help ameliorate issues of location specificity. Hot Dry Rock Geothermal Energy (HDRGE) is one such technology and allows geothermal plants to be located almost anywhere. [52]

Hydropower

Hydroelectric facilities currently generate enough power to supply 28 million households with electricity and, because electricity is generated using water, there is little air pollution. Thus, hydroelectric power is considered to be one of the most reliable, cost-effective, and controllable sources of renewable energy. However, there are some limits on its potential for expanded use beyond that already in operation today. For example, there are very few potential locations for new hydrodams. [53] In addition, droughts that often occur in the Western U.S. can create problems for hydropowered electricity generation. [54] Finally, associated adverse effects of waterway damming, such as altering the habitats of local plant, fish, and animal life, have made them less attractive energy sources. [55]

To counter the adverse environmental effects of hydropower, several new technologies are under development. For example, advanced turbine systems are said to have benefits such as reduced fish mortality, improved compliance with water quality standards, and reductions in carbon dioxide emissions. [56]

Biomass

Biomass resources produce an array of energy-related products including electricity, liquid, solid, and gaseous fuels, heat, chemicals, and other materials. This energy source ranks second to hydropower in renewable U.S. primary energy production. Biomass energy is generated from wood products and byproducts, agricultural byproducts, ethanol, paper pellets, used railroad ties, landfill gas, digester gas, municipal solid waste, and methane. [57, 58] Thus, biomass is often described as “waste-to-energy” fuel. In fact, one production method involving cow manure uses the waste of 10 cows per year to produce enough power to supply the needs of the average American home. Methane from waste landfills is also being used to power facilities such as industrial plants. [59,60]

Hydrogen

Hydrogen is considered a clean energy carrier similar to electricity and can be made from a variety of methods including nuclear energy and renewable resources. One of the most promising hydrogen-based energy systems is hydrogen fuel cells. Interestingly, fuel cells have existed for more than a century, but because they require a constant supply of hydrogen, the limiting challenge has been how to create, store, and

transport the hydrogen. Recognizing this challenge and the potential of hydrogen fuel cells as a source of clean and efficient fuel, the *Hydrogen Fuel Initiative* was announced in 2003 to promote hydrogen fuel cell vehicles from prototypes to in-use models. It is also expected within the next few years that micro fuel cells will be available to power laptop computers and cellular phones. [61, 62]

Traditional, Non-Renewable Energy Generation

The focus of green energy discussions is generally on renewable and clearly green forms of energy production. However, traditional energy sources are also frequently cited in these discussions. For example, coal, gas, oil, and nuclear power are not typically viewed as renewable sources of energy and can have an impact on the environment, yet there are reasons that these energy sources are often part of the green energy discussion.

First and foremost is the issue of sustainability. While the term sustainability is often seen as synonymous with renewability, it is also used in relation to the ability of a country or a region to supply its own energy needs. Dependence on imported oil can be seen as a barrier to U.S. sustainability in terms of energy production and use. Coal, natural gas, and nuclear power offer the chance to provide homegrown energy sources that reduce the reliance on other countries, thus increasing sustainability and also potentially reducing energy costs.

Second, green production techniques and technologies are being explored and applied to these traditional, non-renewable energy sources, as part of efforts to make the use of this type of energy “greener.” Efforts have been made to come up with “clean coal” technology, to use natural gas for large vehicles that cannot be powered by hybrid technology, and to use new drilling techniques for finding oil deposits. Section II-6 discusses carbon capture and sequestration techniques that involve applying green technologies to traditional energy sources. In addition, locating and utilizing energy sources within the U.S. helps to reduce the negative environmental impact caused by shipping products long distances.

Workforce Implications

When considered collectively, the increased potential for growth in renewable sources of energy can be expected to impact employment and occupational expansion. This is generally attributed to the fact that renewable energy production is more labor-intensive than energy source production. It has been estimated that significant investment in the renewable energy segment could result in the creation of more than 650,000 jobs in 10 years and more than 1.4 million jobs by 2025. [63] Other examples of job growth forecasts for the different sources of renewable energy are highlighted below.

- Wind and solar energy production offer 40% more jobs per megawatt of power produced than coal-based production, which is currently the largest fuel source for electricity generation in the U.S. [64]

- The Department of Energy estimates that developing dedicated energy crops could create more than 120,000 jobs by 2012. [65]

- Jobs are being created by the increasing use of ethanol in reformulated gasoline, with some estimating that a 40-million gallon ethanol plant has the potential to create over 1,400 construction jobs and 40 facility operation and maintenance jobs. [66, 67]

- The incorporation of hydrogen fuel cells in automobiles is likely to create a demand for technicians specializing in automotive fuel cell batteries. [68]

- Biomass currently employs roughly 66,000 people with a 200% growth capability related to developing dedicated "energy crops" used for fueling biopower generators. [69]

In terms of the greening of occupations, this sector is likely to have consequences for all three green occupational categories. First, existing occupations that can be classified as green increased demand occupations with growth in employment demand related to renewable energy generation include occupations such as power distributors and dispatchers and power system operators. [70] Second, many occupations are likely to be classified as green enhanced skills occupations with changes in the actual tasks and/or competencies required for occupational performance. For instance, occupations such as power plant operators, electrical engineers, continuous mining machine operators, geological sample test technicians, and mechanical engineers are likely to expand to include new tasks and competencies. [71, 72, 73] Finally, because of the new technologies being used, this sector is likely to witness significant green N&E occupations. Some examples of these novel occupational roles are associated with designing wind turbines or wind farms, assessing wind capacity, technician occupations for wind and geothermal operations, designing or operating biomass or methane facilities, and designing, installing or selling solar equipment.

Section II-2: Transportation

This green economy sector covers activities related to increasing efficiency and/or reducing the environmental impact of various modes of transportation, such as trucking, mass transit, freight rail, and water. Factors directing attention toward this sector include concerns about global warming, fuel shortages and rising costs, and a more general move toward sustainable transportation. The notion of sustainability in transportation centers on systems that meet transportation demands of people, businesses, and

general society, while operating efficiently and limiting emissions, waste, consumption of non-renewable resources, land use, and noise production. [74]

A large proportion of the change occurring in this sector is attributed to increased production of renewable transportation fuels, such as ethanol and biodiesel, development and production of new vehicle engines, and reengineered (eco-friendly) transportation systems. [75] For example, with respect to water transportation, environmentally sensitive changes included having ships use electrical service while in port (versus diesel fuel) and using biodiesel for powering container handling equipment. [76]

Several green technologies are playing a significant role in this sector. One example of such technology is auxiliary power units (APU) in transportation trucks, which reduce environmental impact from emissions as well as decrease fuel costs. [77] Another example of green technology in this sector is hydrogen fuel cells. [78, 79] Significant attention has been directed toward hydrogen fuel cell development and use, including federal legislation (e.g., *2005 Energy Policy Act*) and grants. However, some individuals, such as T. Boone Pickens, have pointed out that fuel cells may lack the power needed for large transportation vehicles (e.g., 18-wheelers) and thus suggest that other alternative transportation fuels, including natural gas, should be concurrently developed. The U.S. Department of Energy also provides numerous grants to support innovation in green transportation technology, recently offering $14.55 million along with matching private funds to total $29.3 million for alternative vehicle technologies. [80]

Workforce Implications

The workplace implications of growing concerns over environmental and conservation issues in the transportation sector should increase demands for individuals with specialized knowledge and skills related to eco-friendly transportation assessment, planning, and logistics. [81] For instance, a significant transition to the use of hydrogen fuel cells would greatly impact occupations involved in automobile production, design and engineering, as well as those that service transportation vehicles. This impact has been estimated to likely result in roughly 20,000 new jobs related to hydrogen fuel cells by 2050. [82] The increased use of alternative transportation fuels in general has been estimated to likely generate 1.5 million jobs directly related to these fuels, as well as roughly 1.4 million jobs in associated fields such as engineering, law, and research. [83]

In terms of the greening of occupations, existing occupations classified as green increased demand occupations include railroad conductors and locomotive engineers. Many existing occupations are likely to be classified as green enhanced skills occupations with changes in the actual tasks and/or competencies that are required for occupational performance. For example, occupations such as automotive specialty technicians, transportation managers, and electronics engineers are likely to expand to include new tasks and competencies. [84, 85, 86] Examples of green N&E occupations include fuel cell engineers and technicians and automotive engineers and technicians.

Section II-3: Energy Efficiency

This sector of the green economy includes activities related to increasing energy efficiency and making energy demand response more effective. Because this sector is closely related to numerous industries, it often defies clear delineation. For instance, most financial investment in this sector is within segments of larger industries (e.g., vehicles, buildings, lighting, appliances). [87, 88, 89] Although a significant portion of this sector involves reducing waste of energy through systematic retrofitting and upgrading of residential and commercial buildings, [90] those green activities will be addressed in a following sector, "Green Construction."

A number of green technologies have been brought to bear in efforts to increase energy efficiency. For example, light-emitting diodes (LED) are a semiconductor technology whose application to general purpose lighting holds the promise of significant energy savings, with currently available products three to four times more efficient than incandescent bulbs. [91] Another example of green technology in this sector is high-performance window technology consisting of low-emissivity coated glass, gas fills, spacers, and improved frames. These high performance windows typically use materials such as fiberglass, vinyl, argon, and silica to reduce energy loss. [92]

The promotion of "smart electrical grids" is also significantly impacting change within this sector. Smart grids employ a number of more specific technologies to meet several criteria set out by the U.S. Department of Energy including self-healing, resisting attack, higher quality power, accommodating generation and storage options, promoting energy markets, and increasing overall efficiency. [93] Technologies used to build and maintain smart grids generally fall into five broad categories shown below. [94]

- *Integrated Communications*: Connection components used for real-time information and control.
- *Sensing and Measurement*: Technologies supporting faster and more accurate response (e.g., remote monitoring, pricing, and demand-side control).
- *Advanced Components*: Component applications from research such as superconductivity, fault tolerance, or power electronics.
- *Advanced Control Methods*: Methods for monitoring components, enabling rapid diagnosis and precise solutions to grid events.
- *Improved Interfaces and Decision Support*: Improved information technology to support faster and more accurate human decision-making.

Workforce Implications

One clear implication from energy efficient technologies and practices is a growing need for individuals with knowledge and skills related to "energy consulting," which represents roughly 40% of this sector's current employment. [95] Another predominant area of employment is related to manufacturing, design, and sales of energy efficient technologies (e.g., low-wattage or zero-wattage lighting products). Finally, occupations that pertain to operations and maintenance have particular relevance to this sector of the green economy. For example, occupations associated with controlling building functions, analyzing energy costs, conserving resources, and enhancing sustainability should see increased demand. [96] Moreover, there is evidence suggesting shortages of skills among the current workforce to meet the future demands of this sector. Such shortages include a lack of reliable installation, maintenance, and inspection services, as well as technical and manufacturing skills. [97]

Green increased demand occupations in this sector are likely to involve growth in employment demand related to energy efficiency-related facility and infrastructure upgrades. For example, occupations such as electrical power line installers and repairers, stationary engineers and boiler operators, and boilermakers are needed for these upgrades. [98] Some occupations may be classified as green enhanced skills occupations with changes in the actual tasks and/or competencies that are required for occupational performance. For instance, occupations such as heating and air conditioning mechanics and installers, and mechanical engineers may expand to include new tasks and competencies. [99, 100, 101] This sector may also see some green N&E occupations related to very specific energy activities being performed on a large scale – for example, new or substantially unique occupations such as occupational roles associated with weatherization or sealing of buildings to improve energy efficiency.

Section II-4: Green Construction

This sector covers activities related to designing and constructing new green buildings, retrofitting residential and commercial buildings, and installing other green construction technology. [102, 103, 104] It has been well documented that to meet the increased demand for environmentally friendly "green" buildings, construction firms have had to substantially change preconstruction designs and materials. [105, 106, 107, 108] Roughly two-thirds of this sector's activities are undertaken by firms that are engaged in design or construction, with the remainder involved with the production and sales of green construction materials. [109]

The broad goals of increasing energy efficiency in residential and commercial structures are likely to foster growth in this green economy sector. Government-sponsored initiatives are central to promoting green construction. For example, recent efforts by the U.S. Environmental Protection Agency's Energy Star® buildings program and the U.S. Green Building Council's LEED™ rating system develop systems by which the energy

and environmental performance of office buildings can be measured and compared to national norms. [110] In addition, the LEED rating system for residential buildings was recently introduced. [111] Several green technologies are also influencing green construction activities. These mainly fall into "mechanical technologies" and include innovations such as on-site electricity generating equipment and blackwater recycling systems. [112]

Workforce Implications

The literature on green construction often cites the benchmark of a 35% reduction in energy consumption by existing commercial and residential buildings over the next three decades. This means that occupations dealing with the manufacture of retrofitting products and their installation will be in demand. Moreover, the increased demand for green retrofitting work will simultaneously promote demand for green building materials, thus increasing the need for occupations in manufacturing industries. [113]

Many existing occupations will be classified as green increased demand occupations, with growth in employment demand related to green construction. That would involve occupations such as carpenters, electricians, cement masons and concrete finishers, and welders, cutters, solderers, and brazers. [114, 115, 116] Similarly, several occupations are likely to be classified as green enhanced skills occupations with changes in the actual tasks and/or competencies required for occupational performance. For example, occupations such as construction managers, civil engineers, and construction and building inspectors, most of whom will be involved in installing and inspecting greener building materials, are likely to expand to include new tasks and competencies. [117, 118. 119] Substantial evidence of green N&E occupations resulting in the creation of new or unique occupations is not clear at this time. [120] However, one example of a green N&E occupation is an energy engineer who develops ways to reduce energy costs in the designing, building, and remodeling stages of construction.

Section II-5: Energy Trading

This green economy sector involves various financial services related to buying and selling energy as an economic commodity, as well as carbon trading projects. [121, 122] At least part of the growth of this sector has stemmed from industry deregulation. [123] Such deregulation has led to the increase of trading electricity as a commodity, also known as "power marketing" or "energy marketing". This business model has been directly adopted by entities commonly referred to as "non-utility generators," typically industrial plants that generate their own power and sell it to utilities or other industrial plants. [124] For example, of the more than 3000 electric utilities in the U.S., over half do not have generating capacity but rather purchase electricity from other utilities. Thus, many electric power plants are seen as commodity-producing investments. [125] In addition to energy marketing, there is a simultaneous push to reduce costs through power conservation.

The other significant portion of this sector is devoted to emission trading, frequently focused on carbon trading. In short, the carbon trading market has developed from caps or limits on the amount of carbon dioxide that can be emitted by a particular entity. Companies or other groups are granted emission permits and must hold an equivalent number of credits that represent the right to emit a specific amount of carbon dioxide. Because of the limiting caps, companies that need to increase their emission allowance need to purchase (trade) credits from other firms. [126]

Workforce Implications

Energy marketing, power conservation, and emissions trading all will have implications for employment and new occupational growth in areas such as auditing, market analysis, brokerage, and so forth. For example, occupations related to both financial analysis and emissions analysis are required for carbon trading. [127, 128]

This sector is not likely to see many green increased demand and green enhanced skills occupations; however, future growth in employment demand related to financial services occupations such as financial analysts and securities, commodities, and financial services sales agents may occur. In addition, this sector may see some green N&E occupations resulting in the creation of new or substantially unique occupations. Some examples of these potentially novel occupational roles are associated with trading or analyzing carbon credits and analyzing and purchasing energy. Growth of these types of occupations, however, may require implementation and application of stricter environmental/pollution regulations similar to those adopted by EU countries.

Section II-6: Energy and Carbon Capture and Storage

This sector covers green economy activities related to capturing and storing energy and/or carbon emissions. [129, 130, 131] The primary force in this sector is the increase in coal-based power plants using integrated gasification combined cycle (IGCC) techniques. The World Coal Institute describes the IGCC technique as follows:

> An alternative to achieving efficiency improvements in conventional pulverised coal-fired power stations is through the use of gasification technology. IGCC plants use a gasifier to convert coal (or other carbon-based materials) to syngas, which drives a combined cycle turbine. Coal is combined with oxygen and steam in the gasifier to produce the syngas, which is mainly H_2 and carbon monoxide (CO). The gas is then cleaned to remove impurities, such as sulphur, and the syngas is used in a gas turbine to produce electricity. Waste heat from the gas turbine is recovered to create steam, which drives a steam turbine, producing more electricity. The result is a combined cycle system. [132]

The benefit of IGCC plants is that they use less water and emit fewer airborne sulfur oxides, nitrogen oxides, particulates, and mercury than conventional pulverized coal

plants. IGCC plants still produce carbon dioxide but this greenhouse gas can be concentrated and removed prior to combustion (i.e., "carbon capture and storage [CCS]). Although IGCC technology is currently being implemented, most experts agree that CCS is farther behind in terms of development and use. [133]

Workforce Implications

Technologies related to carbon capture and storage could generate increased demand for knowledge and skills needed for processes such as geologic or terrestrial carbon sequestration. [134] In addition, demand for individuals to construct and maintain pipelines for carbon transport may increase. [135]

Overall, this sector may not experience significant greening in the immediate future. There may be some green enhanced skills occupations with changes in the actual tasks and/or competencies that are required for occupational performance. One example of such change is for power plant operators. [136] Some green N&E occupations might also be likely. For example, the creation of a unique role associated with carbon capture and sequestration systems. These technologies are still in the research and development stage, so their ultimate workforce impact remains to be seen.

Section II-7: Research, Design, and Consulting Services

This sector encompasses "indirect jobs" to the green economy and includes activities such as energy consulting or research and other related business services. [137, 138, 139] Although not directly related to green technology, these types of occupations have accounted for a significant portion of employment growth in the green economy. For example, it has been estimated that jobs in this sector have grown by 52% since 1990 as compared to a 38% increase in direct jobs during the same time period. [140]

Workforce Implications

Accomplishing this sector's activities requires knowledge and skills in areas such as engineering business consulting, and sales and marketing. This sector is likely to primarily include green increased demand and green enhanced skills occupations through "indirect jobs" or occupations such as financial analysts, sales representatives, geoscientists, engineering managers, marketing managers, and public relations specialists. [141, 142, 143] This sector may also see some green N&E occupations which might result in the creation of new or substantially unique occupations such as occupational roles associated with marketing green products or services as well as research and development engineers of green technology.

Section II-8: Environmental Protection

This sector covers activities related to the environmental remediation, climate change adaption, and ensuring or enhancing air quality. [144, 145, 146] Environmental remediation entails the restoration of a contaminated site to a condition that is not a threat to human or animal health. Numerous technologies are used for remediation efforts including ion exchange, soil washing, chemical precipitation, oxidation, electrolytic treatment, and biological treatments with plants, fungi, and bacteria. [147] Climate change adaptations are "actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected changes in climate conditions." [148] Efforts to enhance air quality generally encompass activities related to minimizing or eliminating various pollutants. According to the U.S. Department of Transportation, these pollutants come from many sources: stationary sources (e.g., factories and power plants), dispersed sources (e.g., dry cleaners and painting operations), mobile sources (e.g., cars, buses, planes, trucks, and trains), and, natural sources (e.g., windblown dust and volcanic eruptions). [149]

Workforce Implications

Federal legislation and regulation have been significant forces in this sector. Below are some examples of such legislation.

- *Clean Air Act of 1990:* Authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and public welfare and to regulate emissions of hazardous air pollutants, as well as provides broader authority to implement and enforce regulations reducing air pollutant emissions.

- *Clean Water Act of 1972:* Establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters.

- *Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (and Superfund Amendments and Reauthorization Act [SARA] of 1986):* Provides a Federal "Superfund" to clean up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and contaminants into the environment. Gives the U.S. EPA the power to seek out those parties responsible for any release and assure their cooperation in the cleanup. [150]

This sector is likely to include green increased demand occupations with growth in employment related to environmental protection in occupations such as environmental scientists and natural sciences managers. [151] Several occupations in this sector are likely to include green enhanced skills occupations with changes in the actual tasks and/or competencies that are required for occupational performance. For instance, occupations such as environmental engineers, hazardous materials removal workers, environmental engineering technicians, atmospheric and space scientists, and soil and

water conservationists may expand to include new tasks and competencies. [152, 153, 154] Finally, this sector is very likely to include green N&E occupations resulting in the creation of new or substantially unique occupations. Some examples of these potentially novel occupational roles are associated with specializing in water resources, redevelopment of "brownfields," analyzing climate change, certifying environmental quality, and industrial ecology.

Section II-9: Agriculture and Forestry

This sector covers activities related to the use of natural pesticides, efficient land management or farming, and aquaculture. [155, 156, 157] Related to the use of natural pesticides is the increase in consumer demand for certified organic foods. According to the International Federation of Organic Agriculture Movements, organic farming is a form of agriculture that maintains soil productivity and controls pests by excluding or limiting the use of synthetic fertilizers and pesticides, plant growth regulators, feed additives, and genetically modified organisms. [158] The increase in consumer demand has contributed to the growth of organic farming and the food products from these farms. For example, from 2001 to 2006 the demand for organic products rose 10% to a total $40 billion in sales. [159]

Efficient land use and management has been facilitated by the application of geospatial technology. A new term, "precision farming," refers to the use of geospatial data and information systems to plan, manage, and evaluate farming processes. [160] This technology uses geospatial information to plan specific agricultural methods to be used in localized areas of an individual farm, with the intention of maximizing crop yields.

Related to mitigating environmental impact of agriculture, it has been estimated that agricultural activities are responsible for nearly 30% of total U.S. methane emissions. [161] To help lessen this impact, green technologies such as "super soil systems" have been developed and implemented. Super soil entails on-farm waste treatment whereby the wastes are reduced to solids and treated liquid effluent streams. These solids are then composted off-site to be cured and used as organic fertilizers and soil enhancements. In addition, a byproduct of these systems is methane gas which can be recycled using "biogas digesters" and then used as fuel for generating electricity. [162]

Workforce Implications

Some of the workforce implications of the activities in this green sector include increased demand for individuals skilled in organic farming methods and the development and research of alternative, non-synthetic pesticides. The use of precision farming techniques requires skills and knowledge related to geospatial technology, such as geographic information systems and global positioning systems. Finally, super soil system technology would create needs for occupations associated with the construction

and manufacturing of the system's components (e.g., large tanks used for "digesting"), as well as the installation of these components. [163]

With regard to the greening of occupations, this sector is likely to have at least some consequences for all three categories of occupations. Some existing occupations that will illustrate green increased demand occupations include agricultural workers and inspectors. [164] Examples of occupations likely to illustrate green enhanced skills occupations include farmers and ranchers, landscape architects, and agricultural technicians, all of which are likely to expand to include new tasks and competencies. [165, 166, 167] Lastly, this sector could include some green N&E occupations where novel occupational roles are generated in areas of precision agriculture and biomass farming in the future.

Section II-10: Manufacturing

This sector covers activities related to industrial manufacturing of green technology as well as energy efficient manufacturing processes. [168, 169, 170, 171] There are two broad facets of green economy activities in the manufacturing sector. The first is the manufacturing of "green" materials that are required by other sectors of the green economy (e.g., renewable energy, construction). The second is the application of techniques and/or technologies to the manufacturing process. This latter category is highly related to previous sectors, such as energy efficiency and carbon capture. According to the Center for Green Manufacturing at the University of Alabama, the purpose of green manufacturing is "to prevent pollution and save energy through the discovery and development of new knowledge that reduces and/or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products or processes." [172]

Workforce Implications

When compared to the other green sectors previously discussed, the primary implication of this sector's activities is the increased demand for existing manufacturing-related occupations. Thus, occupational impact is most likely to be in the forms of green increased demand and green enhanced skills occupations. For example, existing manufacturing occupations such as drilling and boring machine tools setters, operators and tenders, as well as separating, filtering, clarifying, precipitating and still machines setters, operators and tenders are likely to see employment growth due to green economy activities. [173, 174] Green enhanced skills occupations may include occupations such as industrial engineering technicians, electrical engineering technicians, machinists, and occupational health and safety technicians. [175, 176, 177, 178] Green N&E occupations are likely to be found within this sector in relation to the manufacturing of products designed and developed by engineers in such fields as biochemistry, microsystems engineering, and photonics.

Section II-11: Recycling and Waste Reduction

Sector activities encompass solid waste and wastewater management, treatment, and reduction, as well as processing recyclable materials. [179, 180, 181, 182] This sector includes municipal waste and recycling as well as wastewater treatment and management. [183] Many firms within this sector typically specialize in designing and manufacturing water purification products. [184] Other firms focus more heavily on managing recycling and/or waste treatment operations. [185]

Workforce Implications

Significant investments by state and local government programs to increase recycling have facilitated employment demand. For example, studies conducted in 2003 and 2004 found over 50,000 establishments employing over 1.2 million individuals within recycling area of this sector.[186, 187] Similarly, the U.S. Bureau of Labor Statistics forecasts the demand for occupations related to waste management to increase by 14% between 2006 and 2016. [188] Some green enhanced skills occupations could include employment growth in existing occupations such as plant and systems operators as well as refuse and recyclable materials collectors. [189] Green N&E occupations in this sector could create potentially new occupational roles associated with sustainable design, recycling and reclamation, and coordinating recycling activities.

Section II-12: Governmental and Regulatory Administration

This sector includes activities by public and private organizations associated with conservation and pollution prevention, regulations enforcement, and policy analysis and advocacy. [190, 191, 192, 193, 194] Within public or governmental organizations, many of this sector's activities involve conservation and pollution prevention efforts and creating and enforcing regulations. [195] In addition, non-profit organizations are frequently involved with policy analysis and advocacy of conservation, climate change, and other energy-related issues. [196] Profit-oriented organizations, such as venture capitalists and private equity firms, are often engaged in financing small- and large-scale renewable energy projects and other green technology projects. [197]

Workforce Implications

An increase in the activities related to this green economy sector would translate into a demand for both specialist-type occupations (e.g., testing specialists, researchers) and more general occupations related to regulation or administration (e.g., compliance managers, policy advisors). With regard to the greening of occupations, this sector is likely to have at least some consequences for all three occupational categories. Some existing occupations that will be classified as green increased demand occupations include agriculture inspectors. [198] In terms of green enhanced skills occupations,

occupations such as soil and water conservationists and environmental engineers are likely to expand to include new tasks and competencies. [199] Finally, as stricter regulations are adopted and enforced, this sector could include some green N&E occupations where novel occupational roles are generated in areas of consulting in sustainability, air quality control, consulting in gas emissions permits, and verification of emissions reporting.

SECTION III: EXISTING O*NET-SOC OCCUPATIONS AND NEW & EMERGING (N&E) OCCUPATIONS IN THE GREEN ECONOMY

Section III-1: Framework and Procedural Description

The primary purpose of this report is the identification of current O*NET-SOC occupations impacted by the green economy and the identification and viability of potential new and emerging occupations within the green economy. Occupations identified in this report as undergoing "greening" come from three sources: (a) occupations in the current O*NET-SOC 2006 taxonomy, [200] (b) O*NET-SOC N&E occupations identified through research conducted on in-demand industry clusters, [201] and (c) N&E occupations identified in the current research on the greening of the world of work. Existing O*NET-SOC occupations in the 2006 taxonomy experiencing an increase in employment demand but no significant changes in the work and worker requirements are designated as "green increased demand" occupations. "Green enhanced skills" occupations include existing O*NET-SOC 2006 taxonomy occupations where the essential purpose of the occupation remains the same, but tasks, skills, knowledge, and other such elements have been altered due to the impact of green economy activities and technologies.

In relation to the O*NET system, new and emerging (N&E) occupations are defined as (a) occupations that involve significantly different work from that performed by incumbents of other occupations and (b) are not adequately reflected by the existing O*NET system. [202] Candidate N&E occupations that do not perform work significantly different from the work of existing O*NET occupations are not considered N&E occupations.

Within the context of occupations impacted by the green economy, this definition of N&E occupations (both those in the green economy and in in-demand industry clusters) equates to "green N&E" occupations. That is, green N&E occupations are those occupations for which the *impact of green economy activities and technologies is significant enough to create the need for unique work and worker requirements, which results in the generation of a new occupation*.

A systematic process was followed to identify existing O*NET-SOC occupations, N&E occupations from previous research undergoing "greening," and N&E candidate occupations in the green economy. The major steps and activities of this process are outlined below. It is important to note that many of these steps were designed and implemented in previous efforts to identify N&E occupations in a number of in-demand industry clusters. [203]

1. *Locate and Review Existing Literature*. The purpose of this initial activity was to gather every possible research report and article pertaining to green economy activities – especially those oriented toward "green jobs." More than 60 reports were collected and reviewed. These reports were from reputable sources such as recognized educational institutions, articles published in established academic journals, commissioned reports, industry white papers, and governmental technical reports. Additionally, numerous associated/relevant internet sources on the world of work were reviewed.

2. *Identify and Compile Job Titles*. This step entailed accumulating a listing of all job titles that were referenced in the source reports. Such titles were derived from explicit references or from discussions within the bodies of the reports. These titles were input into a master spreadsheet.

3. *Review and Sort Collected Job Titles*. The master spreadsheet was reviewed to eliminate the roughly 2% of titles considered redundant or either too molecular (e.g., individual positions) or too molar (e.g., occupational clusters) to be useful. Titles were also sorted into five broad groupings to facilitate interpretation (construction, transportation, energy, materials, and other). A total of 467 titles were retained and sorted.

4. *Cluster Titles to Identify Occupations*. Within each grouping, similar job titles were clustered and differentiated occupational titles retained. For example, power plant operations job titles were separated from power plant design job titles or environmental job titles were separated from sales/marketing job titles. Subclusters were also formed within the broad groupings to further eliminate redundancies and to ensure that similar titles were clustered. For example, the "materials" grouping was further divided into building, design, and hazardous materials.

5. *Identify Occupational Sectors*. To further organize the research, the source reports were again reviewed to collect lists of the organizational schemas commonly used to sort so-called green jobs. This review produced a 12-sector schema that was consistent with what was used in the source reports and provided the most logical and detailed approach to classifying occupations.

6. *Determine Overlap with O*NET Occupations*. In this step all titles were reviewed to determine whether they were (a) a direct match to an existing O*NET-SOC occupation (*green increased demand occupations*), see Appendix A, (b) a close match to an existing O*NET-SOC occupation, but had aspects that could merit task list updating and/or alternate title changes for the existing O*NET-SOC entry (*green enhanced skills occupations*), see Appendix B, or (c) a possibly new or unique occupational title relative to the O*NET database (*green N&E occupations*), see Appendix C. Two occupational analysts assigned the titles to these three categories. This assignment was conducted independently and

interrater agreement was 95%. Disagreements were discussed and titles assigned.

7. *Identify Potential Green Economy N&E Occupations*. This step focused on occupations in the green N&E occupational category. Classifying potential N&E occupations into the 12 organizational sectors facilitated research by creating conceptually similar groups on which to focus efforts. In addition, taking a sector-centric approach also helped to surface important green technologies that are driving occupational changes. These sectors were presented in Section II of this report.

8. *Research Potential Green Economy N&E Occupations.* The green economy reports from step 1 were used as the primary sources of evidence in this step. However, numerous internet sources were also searched in an effort to locate additional evidence. Credibility of these additional sources was ensured by focusing searching activities on governmental sources, professional/industry associations, state and local agencies and organizations. Each occupational title was researched to determine first if it was a sufficiently viable title to warrant N&E inclusion. Titles were discarded if it became impossible to determine even the most general work activities performed by incumbents who might use that title, or if there was no indication that the title was in common use. Other titles were combined with similar titles when research determined that the work activities in both were essentially the same. Finally, the retained titles were compiled for more rigorous research. All existing N&E occupations previously identified in in-demand industry cluster research were also examined to determine green N&E occupational classification.

9. *Build and Consolidate Evidence for Final N&E Determination.* Six specific criteria used in previous N&E research were again used to determine the N&E status for the occupations from step 7.

    - Reputable evidence of significant employment (i.e., at least 5000 incumbents).
    - Evidence of positive employment growth in the candidate occupation over the next five years
    - Existing accredited education/training programs/institutions offering credentials tailored for the candidate occupation
    - States requiring licensure, registration, or certification in order to practice in the occupation
    - Evidence of national associations serving incumbents in the occupation, with a benchmark of at least one such association.
    - Evidence of trade or professional journals dedicated to incumbents in that occupation, with a benchmark of at least one such association.

10. *Compile and Report N&E Evidence*. Forty-five occupations identified in the green economy met the criteria to be considered new and emerging. Forty-five existing N&E occupations identified in previous research of in-demand industry clusters were also considered to be part of the green economy. The results of this research are shown in Appendix C of this report.

In summary, the current research identified a total of 64 O*NET-SOC occupations from the 2006 taxonomy as “green increased demand” occupations and 60 O*NET-SOC occupations as “green enhanced skills” occupations. Forty-five O*NET-SOC N&E occupations previously identified through research on in-demand industry clusters and 46 newly identified N&E occupations in the green economy qualified as “green N&E” occupations. Because of its constantly evolving nature, the green economy will be researched continually in an effort to see how it is impacting the world of work and, in particular, O*NET-SOC occupations and the emergence of new occupations. This research will help ensure that the O*NET system includes the most up-to-date information on occupations in the green economy.

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