EMERGING GREEN INDUSTRIES IN ARIZONA: DEFINITIONS, INDUSTRY BASE, AND OPPORTUNITY AREAS

PREPARED BY:

BATTELLE TECHNOLOGY PARTNERSHIP PRACTICE

Battelle
The Business of Innovation

IN COLLABORATION WITH

COUNCIL FOR COMMUNITY AND ECONOMIC RESEARCH

C2ER | THE COUNCIL FOR COMMUNITY AND ECONOMIC RESEARCH

PREPARED FOR:

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the Arizona Green Economy Advisory Committee members for their insights on the report.

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In addition, a Green Economy Project Steering Committee of Arizona Commerce staff also provided invaluable guidance in the development and direction of the report. That committee has included input from Rosalyn Boxer, Frank Curtis, Olivia Doherty, Henry Ekweani, Aruna Murthy, Debra Raeder, and Jessica Smothermon.

The research results or any implied recommendations do not reflect a consensus opinion of the members of either the Green Economy Advisory Committee or the Project Steering Committee.

EXECUTIVE HIGHLIGHTS:
EMERGING GREEN INDUSTRIES IN ARIZONA

The State of Arizona received a $1.2 million Labor Market Information (LMI) improvement grant from the U.S. Department of Labor in November 2009 as part of the American Recovery and Reinvestment Act of 2009. The grant provides resources to the Arizona Commerce Authority's Research office to assess the state's green economy, measure the number of jobs available, and provide baseline information about where future job opportunities will likely be in this emerging sector. The project is being advised by a statewide group of business, government, and academic leaders with expertise in various aspects of the green economy.

A national research team, led by the Council for Community and Economic Research (C2ER), is providing research assistance. The project's first major deliverable is a study of industry trends in the green economy, conducted by the Battelle Technology Partnership in collaboration with C2ER. The report provides key findings about the state's footprint in the green economy.

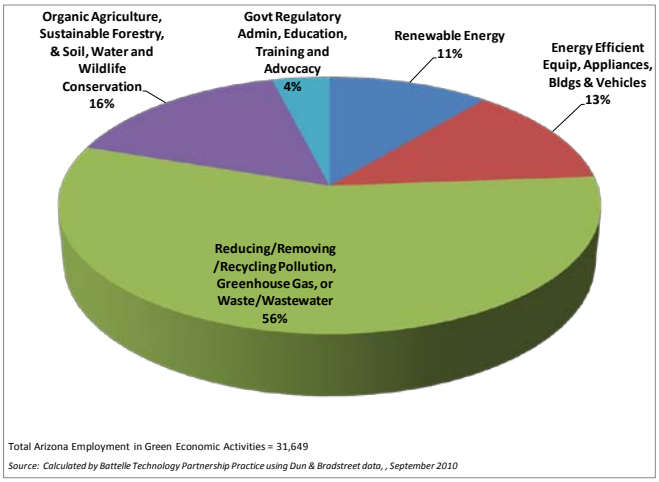
THE GREEN ECONOMY IN ARIZONA

Earlier in 2010, Arizona's private and public green employment totaled an estimated **31,649 jobs** in **1,711** establishments.

Arizona's largest employing green-economy segments include:

1. Waste Mgt. & Treatment 9,762 jobs
2. Conservation 4,643
3. Recycling 2,887
4. Energy Efficient Building Products & Materials 2,234
5. Environmental Research & Consulting Services 1,746
6. Solar PV and Thermal Energy 1,496

Figure 1: Employment in Arizona's Green Economic Output-Related Establishments, Sept. 2010



Total Arizona Employment in Green Economic Activities = 31,649

Source: Calculated by Battelle Technology Partnership Practice using Dun & Bradstreet data, , September 2010

ARIZONA'S STRATEGIC OPPORTUNITIES IN GREEN ECONOMIC SECTORS

Solar Photovoltaic (PV) Energy

- One of the nation's largest solar installation contractor communities
- Access to a substantial semiconductor industry and research infrastructure

Solar Thermal Energy

- Significant sun hours and vast amounts of undeveloped land offer substantial potential for developing new projects that are less susceptible to extreme heat

Wind Energy

- Limited in terms of energy production due to modest wind speeds
- Links to the global supply chain for wind frame production through the entrepreneurial success of several companies located in the state

Biofuels/Biomass

- Significant amount of next generation, algae-based biofuel development in the state
- Critical research capacity available at Arizona State University's Laboratory for Algae Research and Biotechnology

Energy Efficiency and "Green" Building Systems

- Relatively small number of LEED certified buildings (102) or facilities that qualify for the U.S. EPA/U.S. DoE Energy Star designation (139) when compared to other states
- Significant production capacity for building products and materials used in green buildings

Water Efficiency and Management

- National leader in research activities around water management and protection with major National Science Foundation and U.S. Department of Agriculture grants
- National leader in its regulatory approaches to the deployment and development of water reuse systems, including gray water

Next Steps in Understanding the State's Green Economy

Research continues on this topic through a statewide survey of more than 10,000 companies to identify green occupations, including those that might not be in what we traditionally consider "green" companies. Data from that research (due in the Fall 2010) will guide the state's workforce development policy by helping to link jobseekers seeking "green" jobs with available job openings. This work is being closely aligned with a $6 million federally funded State Energy Sector Partnership Grant designed to place people in green jobs. In addition, the research team will monitor job vacancies in the green economy and profile key occupations to help today's youth and jobseekers identify clear pathways and market intelligence for youths considering future green careers.

I. INTRODUCTION

This report is part of a broader effort of research studies, data collection efforts, and data dissemination initiatives for the Arizona Commerce Authority/Arizona Department of Commerce to improve the state's understanding of its "green economy," which is being led by the Council for Community and Economic Research (C2ER). The key objectives of this initiative are to promote and improve the dissemination of intelligence on the green economy in Arizona, provide a foundation for future analysis, and enhance the skills of the Arizona Labor Market Information staff.

The focus of this report is to provide an understanding of:

- What is the green economy?
- What are the industry drivers of the green economy?
- What is the current industry footprint of the green economy in Arizona?
- What are the indicators to best track the development of the green economy in Arizona?

This report was prepared by the Battelle Technology Partnership Practice, the technology-based economic development arm of the world's largest nonprofit R&D organization with revenues of over $5 billion. Across its organization, Battelle is a global leader in green technology development, with expertise that encompasses all segments of the green economy and includes managing national laboratories for the U.S. Department of Energy. The Battelle Technology Partnership brings nationally recognized expertise in assessing technology-based economic activities and core technology competencies of regions and states, together with the ability to translate these assessments into strategic action plans.

Battelle TPP also has a strong knowledge of Arizona. Over the years, Battelle TPP has worked extensively in Arizona, developing and assisting in the implementation of Arizona Biosciences Roadmap, as well as advancing an Arizona Sustainable Systems Investment Prospectus and technology studies in Advanced Manufacturing and Advanced Information Technology and Communications.

II. DEFINING THE GREEN ECONOMY

As we enter the second decade of the 21st century, the emergence of green industries has taken on a new urgency. In past decades, the advancement of environmental laws and regulations to address problems from air pollution, contaminated water, and hazardous/solid waste, among other environmental threats fueled the establishment of what might be termed the "first wave" of the green economy – traditional environmental industries. These environmental industries that took form to address new laws and regulations involved pollution abatement equipment, remediation products and services, waste water treatment, and recycling as well as more professional services for environmental testing and impact analysis. While these traditional environmental industries have had a significant role in improving the quality of our environment, they have not reached the stature of other emerging economic sectors in recent decades, such as information technology, biosciences or telecommunications. By 2008, the employment from traditional environmental industries (NAICS 562) in the U.S. reached 356,754 workers or 0.32% of the overall U.S. private industry employment and in Arizona 4,445 workers and 0.20% of the state's private industry employment.

In recent years, as the 21st Century has moved forward, the growing concerns about the environmental impacts of climate change, as well as the rising costs, and uncertainty about oil supplies and the national defense and homeland security interests in ensuring energy independence have once again propelled the green economy into the limelight. Now the discussion is about renewable energy, energy efficiency, and greenhouse gas reduction. The green economy today is viewed by many as an emerging technology-based economic driver for advancing energy independence, new firm development, and job creation – as well as a means to addressing growing environmental concerns, particularly associated with climate change.

But arriving at a definition of what are green industries has proven to be elusive. There is no doubt that the green economy is coming and it is shaping up to be a broad-based phenomenon that will change the way the entire economy operates. Yet, it is hard to find consensus on what is and is not a green industry.

A. ELUSIVE DEFINITION OF GREEN INDUSTRIES

A growing number of studies, particularly for states and regions, have had to wrestle with the question of what is a green industry (see Appendix A for a listing and brief description of some of these studies). The impetus for conducting these studies has typically focused on the new wave of green economic development focused around renewable energy development, whether it be the economic activities to advance technologies and generate renewable energy (i.e., wind, solar, biomass, etc.) or to address enabling technologies that are critical to advancing the mainstream use of these new renewable energy sources (i.e., energy storage, grid technologies, etc.).

But what is beginning to emerge is a broader sense that the green economy also addresses improvements in energy efficiency and activities to reduce environmental impact or address environmental issues. Often these studies are using the term "cleantech" to define the green

economy. But there are still variations across the studies, so there is not one widely acknowledged definition of the industries that comprise the green economy.

Among the common element in defining the green economy from a review of these studies are:

- **Renewable energy and fuels**, including wind; solar PV & thermal; geothermal; hydropower; ocean/tidal/wave power; fuel cells; biofuels (e.g., ethanol, biodiesel, biogas, solid);
- **Energy storage and management,** including batteries; hydrogen; smart grid systems; carbon sequestration
- **Energy efficiency products and services,** including advanced lighting; energy efficient appliances, HVAC, and building materials; building controls and automation
- **Green materials,** including bio-based polymers, materials, and fabrics; advanced composites used for energy efficiency applications; green chemicals & solvents; products made of recycled materials

However, significant variations arise across these studies in the definition of the green economy which focus on:

- **Alternative energy**, with few of the existing studies including nuclear and clean coal.
- **Traditional environmental industries**, with many existing studies not including these industries involved in conservation and pollution prevention products and services, such as air quality control, water purification, sewage treatment, pollution prevention and remediation products and services.
- **Agriculture,** with a few studies including as green companies those involving crop yield improvements to using natural fertilizers to implementing sustainable land management technologies.
- **Transportation**, with most studies including hybrid fuel vehicles, but variation taking place in whether to include certain logistics activities.
- **Professional services**, with a few studies including professional services as investment banking, venture capital, and marketing serving green companies
- **Non-profit advocacy**, with a few studies including non-profit advocacy groups supporting the green economy as green companies

These existing studies suggest that the green economy is a broad collection of activities, technologies, and markets and there are considerable differences in emphasis of what is important to different communities. The next section considers an Arizona point of view.

B. Advancing a More Rigorous Definition of the Green Economy

As this effort began, the Project's Advisory Committee, consisting of a group of Arizona stakeholders, also wrestled with the definition of green economy. As in the various studies referenced above, these stakeholders also had wide ranging views of the "definition" of the green economy. Consensus was fairly easily achieved with regard to renewable energy and energy efficiency activities; however, mixed views and perspectives impacted how "green" areas such as nuclear power, environmental services, and financial firms were perceived.

The lack of a commonly accepted definition of the green economy calls for a more rigorous set of general principles to advance an understanding of the green economy. Fortunately, the U.S. Bureau of Labor Statistics (BLS) has set out a comprehensive approach and general principles to define the green economy and with it incorporated a NAICS-based structure for categorizing green economy establishments.[1]

The starting point for BLS is that green economy encompasses ***"economic activities that help protect or restore the environment or conserve natural resources."*** In this regard, BLS embraces traditional environmental industries as being a central component of the green economy and so creates continuity over time.

The approach set out by BLS also embraces the general principle that to be a green activity there must be an environmental value-added component, which reflects the thinking behind Eurostat's "Handbook on the Environmental Goods and Services Sector."[2] Under this value-added approach, standard products or services used in both environmental and non-environmental activities are not counted as green. As the BLS explains:

"In specifying green goods and services, BLS has identified whether a good or service has a discernible positive impact on the environment or natural resources conservation."

According to BLS, these positive or value added impacts on the environment or natural resources conservation can occur because the economic activity involves:

- The direct production of green goods and services, which are produced specifically for the purpose of protecting or restoring the environment.

[1] An initial draft for comments was issued in the March 16, 2010 Federal Register for comments and was finalized in the September 21, 2010 Federal Register, which presented comments, BLS responses and BLS final definition to be used for data collection.

[2] Eurostat, "Handbook on the Environmental Goods and Services Sector," (Luxembourg: 2009). Eurostat counts only those producers who are "final producers" of green products, not suppliers of non-environmental inputs, or distributors/retailers of the final product. Likewise, Eurostat mandates that the goods and services must be produced for the environment, which is to say they must have an "environmental purpose," where purpose refers to performing a set of certain environmental activities regardless of intention. We will not use this phrasing as it may lead to confusion.

- The indirect production of green goods and services, which are produced for another purpose, but have a favorable impact on protecting or restoring the environment or conserving natural resources relative to other goods or services generally used for the same purpose, such as electricity produced from renewable sources or hybrid vehicles.

- Specialized inputs used only in the production for a direct or indirect green good or service, such as a wind turbine blade or fertilizer for organic crops.

- A service that specializes in the distribution of green goods, including specialized transportation, warehousing, and wholesale or retail trade services for green direct or indirect goods and services.

Based on its view of green economic activities as those helping to protect or restore the environment or conserve natural resources, the draft approach set out by BLS identified five categories of objective and measurable economic activities that comprise green economic activities:

1. Renewable Energy – including hydropower, wind, biomass, geothermal, solar, tidal, and hydrogen fuel cells, among other renewable sources.

2. Energy Efficiency Equipment, Appliances, Buildings and Vehicles Goods and Services – including production of energy efficient products, cogeneration and increasing the energy efficiency of industry processes.

3. Pollution Mitigation, Greenhouse Gas Reduction and Recycling and Reuse of Goods and Services – including activities that reduce the emission of pollutants and remove pollutants and hazardous waste from the environment, nuclear energy, clean coal and other means to reduce greenhouse gas emissions in electricity generation from fossil fuels, and activities that collect and recycle materials and waste water

4. Organic agriculture, Sustainable forestry and Soil, Water and Wildlife Conservation Agricultural and natural resources conservation including reducing use of chemical fertilizers and pesticides, soil and water conservation, sustainable forestry, land management and wildlife conservation.

5. Governmental and Regulatory Administration, and Education, Training and Advocacy Goods and Services related to activities to develop and enforce environmental regulations, increase public awareness of environmental issues and provide training in the application of green technologies and practices.

Battelle has cross-walked these five BLS categories into a set of more commonly understood and detailed segments of green economic activities, such as further breaking out the renewable energy category into solar photovoltaic (PV) energy, solar thermal energy, wind energy, etc. The description of current Arizona "green" industry base in the next section uses this category and segment structure (as detailed in Appendix B).

III. LIKELY DEMAND DRIVERS FOR THE GLOBAL GREEN ECONOMY

In considering the industry drivers of the green economy, both in the U.S. and abroad, it is particularly important to consider where the demand for the green economy is likely to be strongest. Globally, the green economy is nearly a $5 trillion market, with traditional environmental activities accounting for about 22% of the global total and the remainder more of the emerging green economy found in renewable energy, energy efficiency and greenhouse gas emissions.

A detailed examination of the global marketplace commissioned by the United Kingdom's Department of Business Enterprise and Regulatory Reform and released in March of 2009 finds that the sectors with the largest market values and highest growth rates are largely in the emerging renewable energy, energy efficiency and greenhouse gas emissions.[3] Those product groups providing the best overall opportunities are:

- Wind Energy
- Solar Photovoltaics
- Alternative Fuels
- Geothermal
- Biomass
- Building Technologies
- Alternative Fuels for Vehicles
- Recovery and Recycling

Sectors with the lowest growth and some of the smallest market values are primarily in the traditional environmental sector. In its detailed industry analysis, there were no environmental subsectors in the top 72 products and services for the green economy based on market value and current growth rates. Many of the products and services in the environmental sector are reaching maturity, and opportunities in this sector thus lie in very specific areas. There are also opportunities in international trade to developing nations, where local competition is low and there is demand for transfer of technologies and services to improve infrastructure; where there is a sufficient level of market demand; and where there are contestable markets (i.e., those where local and international competitors do not hold market dominance positions). One example is the Water and Wastewater Treatment industry, which currently has large export market values.

Clean Edge in its report on "Clean Energy Trends 2010" reports that among the three leading green economic activities will be:

- Biofuels (global production and wholesale pricing of ethanol and biodiesel) reached $44.9 billion in 2009 and are projected to grow to $112.5 billion by 2019. In 2009 the biofuels

[3] U.K. Department of Business Enterprise and Regulatory Reform, Low Carbon and Environmental Goods and Services: An Industry Analysis, March 2009

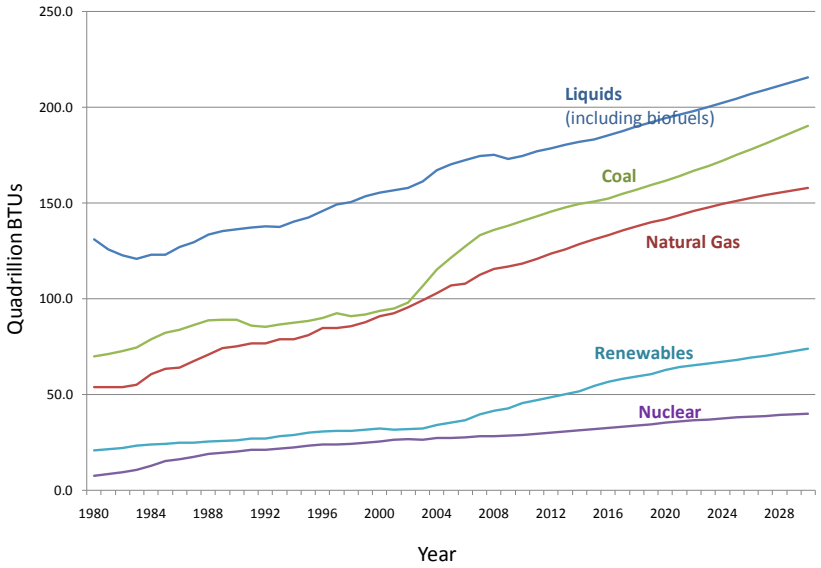
market consisted of more than 23.6 billion gallons of ethanol and biodiesel production worldwide.

- Wind power (new installation capital costs) is projected to expand from $63.5 billion in 2009 to $114.5 billion in 2019. Last year's [2008 or 2009?] global wind power installations reached a record 37,500 MW. China, the global leader in new installations for the first time, accounted for more than a third of new installations, or 13,000 MW.

- Solar photovoltaics (including modules, system components, and installation) will grow from a $36.1 billion industry in 2009 to $116.5 billion by 2019. New installations reached just more than 7 GW worldwide in 2009, a sevenfold increase from five years earlier, when the solar PV market reached the gigawatt milestone for the first time. But because of rapidly declining solar PV prices, industry revenue between 2008 and 2009 was down about 6 percent – from a revised $38.5 billion in 2008 – as solar prices dropped from an average $7 peak watt installed in 2008 to $5.12 peak watt installed last year.

But to fully understand the demand drivers for the green economy, ***it is critical to recognize that we are entering a new energy era in which no single type of energy will dominate***. The U.S. Energy Information Administration projects that a broad mix of energy sources – liquid fuels (both fossil oil and biofuels), coal, natural gas, nuclear and renewable energy sources will be needed to meet demand. As Figure 1 below illustrates, each of these energy sources will experience increasing levels of demand for the foreseeable future (projected through 2030):

Figure 1: World Energy Use by Fuel Type – 1980 through 2030.[4]



So the market forces at work will mean that renewable energy and greenhouse gas reduction efforts will be needed to address the rising demand for energy from our global economy. As this demand for energy continues to mount, energy efficiency will also take on greater importance.

[4] Sources: History: Energy Information Administration (EIA), "International Energy Annual 2006 (June-December 2008), web site www.eia.doe.gov/

The likelihood of some degree of regulations and perhaps even a cap-and-trade system on carbon emissions is quite high, further driving the importance of renewable energy, greenhouse gas reduction and energy efficiency.

This means that the new wave of the green economy focused on energy and climate change is not a passing fancy, nor likely to be of minimal consequence as an economic driver as traditional environmental industries have played out. Instead, it is most likely that we are at the start-up phase of a major new economic growth engine.

IV. TRACKING ARIZONA'S PRIMARY GREEN INDUSTRIES

The Advisory Committee agreed that the BLS approach offers a comprehensive definition that is both rigorous and objective. The five categories of green economic activities also enable sufficient distinctions so that users of the data can understand the different dimensions of green economic activities underway in Arizona. The Advisory Committee did appreciate the more detailed segments that Battelle identified as offering more specifics about the state's green industries.

So the next question is how to measure these green economic activities. The draft approach set out by BLS suggests that from an industry perspective, rather than an occupational perspective, the focus should be on identifying establishments that produce green goods and services – or what they term the "output approach." In this output approach, BLS is concerned with the jobs related to industries producing a specific set of goods and services which fall within the five green categories, even if many of these jobs are involved in non-green activities such as financial and administrative services, marketing, etc. This is not unlike what is currently done to measure jobs in other knowledge-based industries, such as biosciences or information technology, where not all of the workers in these industries are in occupations that reflect those knowledge activities.

It is important to recognize that accounting for this green industry workforce is different from measuring the number of workers in green occupations. Many non-green firms will use environmentally-friendly production processes and practices, such as generating solar power for use within a store or factory or collecting and recycling waste created during a manufacturing process. Likewise, some firms will also employ workers with primary duties related to these environmentally-friendly activities.

Below is the measurement of industries involved in green economic output activities in Arizona. It is based on work that Battelle undertook to identify establishments that fall into one of the five categories of green products and services set out by BLS.

The process for identifying a green economic output-related establishment is particularly challenging. As BLS explains in the March 16, 2010 Federal Register Notice, "The studies reviewed showed that neither of the standard classification systems used in the BLS data, the North American Industry Classification System (NAICS) and the Standard Occupational Classification (SOC), identifies a green or environmental grouping of industries or occupations." Other than a few traditional environmental industries, there is no existing industry classification for green industries such as solar energy, energy efficient products, green materials or reduction of greenhouse gases.

The approach that Battelle undertook was to examine a wide assortment of listings of firms involved in green economic activities. For many of these green economic activities, such as energy efficient products or green building materials, Battelle was able to make use of certifications from federal, state, and industry organizations. For others, Battelle was able to identify green firms based on venture capital funding, issued patents, and federal grants awarded for green activities. Battelle also examined listings of membership in state organizations and national associations involved in focused green activities, such as solar energy, wind energy, hydropower, and renewable fuels, among others. Battelle also considered listings from market research organizations and

proprietary industry data sources, such as Environmental Business Journal and Plunkett's Alternative Energy. And finally, key Dun & Bradstreet industry codes directly relating to green economy activities were included. Appendix C provides the listings that Battelle examined to identify green firms.

To identify which green firms have establishments in Arizona, Battelle used the Dun & Bradstreet company database, which provides the most comprehensive and publicly available listing of firms and operations across the nation. The existence and operations of these firms were also verified to the extent possible through the examination of company websites and phone calls. For firms not listed in Dun & Bradstreet (D&B), Battelle looked them up on the web to attempt to identify those with business locations in Arizona.

Altogether, Battelle identified 1,711 establishments involved in the green economic output-related activities in Arizona.[5] The green industry category with the most establishments was pollution reduction and clean-up, which had 751 establishments, more than double the next highest green industry category. This is not surprising since pollution reduction and clean-up is associated with the longer standing traditional environmental industries.

The growing presence of green industries in Arizona also is revealed. Arizona had well over 150 establishments in all of the other green industry categories, except greenhouse gas reduction and education, compliance & training.

Of particular note in non-traditional environmental firms is Arizona's focus on:

- Solar PV energy and solar thermal energy, with 95 and 38 establishments, respectively, or a total of 133 establishments involved in solar energy
- Energy efficient building products and materials, with 116 establishments
- Energy Auditing with 40 establishments providing additional consulting services

Table 1 below provides the numbers of establishments by broad BLS green industry category and by Battelle's more detailed sub-categories. Employment figures reported by D&B are also presented. These employment figures are obtained by D&B representatives in the process of updating marketing and credit reports. However, the exactness and specificity of these numbers are often debated. To provide an additional employment perspective C2ER, under an agreement with the Arizona LMI office, is presently reviewing this listing of green economic output-related establishments from Battelle to match against Arizona's records of payroll-related employment. It is expected that all of the major BLS green industry categories will be able to be reported using the payroll-related employment figures, except for greenhouse gas reduction and education, compliance and training which have too few number of establishments and so would violate disclosure restrictions of payroll-related employment. Most of the detailed green industry segments identified by Battelle will not be able to be reported using the BLS payroll-based employment due to disclosure issues stemming from too few establishments.

[5] The definition of "establishment" within the context of D&B data represents a geographical location where a company does business. This may or may not correspond to the BLS definition of an "establishment" for its data collection purposes.

Table 1
Battelle Identified Green Economic Output-Related Establishments in Arizona and Current Employment Based on D&B Records

BLS Categories and Battelle Detailed Segments	Establishments	D&B Current Reported Employment
Renewable Energy	**164**	**3,519**
Biofuels/Biomass	15	159
Hydropower Energy	1	1,500
Solar PV Energy	95	936
Solar Thermal Energy	38	560
Waste-to-Energy	1	9
Wind Energy	8	359
Other	6	19
Energy Efficient Equipment, Appliances, Building & Vehicles	**204**	**4,013**
Architecture & Building Design	11	330
Battery & Energy Storage Technologies	4	142
Electric/Hybrid Drive Technologies & Vehicles	2	7
Energy Consulting & Auditing	40	425
Energy Efficient Appliances	5	191
Energy Efficient Building Products & Materials	116	2,234
Energy Efficient HVAC	10	514
Energy Efficient Lighting	5	29
Fuel Cells	3	58
Hybrid Drive Technologies/Vehicles	2	2
Other Energy Efficient Products	4	69
Water Efficient Products	1	10
Smart Grid Systems/Smart Metering	1	2
Reducing or Removing Pollution, Greenhouse Gas Reduction and Recycling or Reusing Waste Materials or Wastewater	**1,058**	**17,824**
Air & Water Purification Technologies	2	68
Air/Water/Sewage/Solid Waste Management & Treatment	353	9,762
Environmental Research & Consulting Services	279	1,746
Green Building Products & Construction Materials, NEC	18	673
Green Chemicals	19	400
Other Green Products	4	105
Pollution Prevention	20	97
Remediation Technologies & Services	56	826
Clean Coal	1	9
Nuclear Energy	5	211
Other	13	79

BLS Categories and Battelle Detailed Segments	Establishments	D&B Current Reported Employment
Public Mass Transit	1	4
Recycled-Content Products	9	957
Recycling	277	2,887
Organic Agriculture, Sustainable Forestry and Soil, Water and Wildlife Conservation	**258**	**5,019**
Organic Farms & Organic Food Production	12	376
Conservation	246	4,643
Governmental and Regulatory Administration, Education, Training and Advocacy Goods and Services	**28**	**1,251**
Compliance	24	1,094
Training	4	157
Grand Total	**1,711**	**31,649**

V. ASSESSING ARIZONA'S FUTURE POSITION IN GREEN ECONOMY DEVELOPMENT

Much of the green economy is still in an emerging stage of development with strong future growth expected, particularly in renewable energy, greenhouse gas reduction and energy efficiency sectors, as discussed earlier. This suggests states that are able to advance innovation in green technologies can be among the leaders of this green economy. So while understanding the current industry size and structure is important, it is also critical to look towards the future and determine whether the innovation pillars for green industry development in Arizona are in place and in which segments these pillars may also point to development opportunities.

To help inform what indicators are critical for assessing Arizona's position in the green economy, Battelle and C2ER conducted focus groups and one-on-one meetings across Arizona involving over 80 participants involved in green industry activities or key community stakeholders.

Among the topics discussed at these focus group and one-on-one meetings were:

- What are the key competitiveness and growth issues driving the green economy
- How can we best measure green economy development in Arizona?

On the topic of key competitiveness and growth issues, we learned the following from the participants in the focus groups and one-on-one meetings:

- **Importance of public sector incentives and required standards to fueling adoption of green activities – especially critical for green buildings and solar installation.** According to the focus group participants, Arizona has stepped up in terms of offering solar rebates, but the state and its local governments are uneven in advancing public green building standards. In particular, the state's efforts were seen as limited because there is no funding to meet an existing executive order advancing green building standards.

  Another important area of leadership by Arizona in terms of required standards is the state's gray water requirements—an important, but unrecognized, driver. These gray water standards are impacting how both landscaping and the recycling of water are undertaken.

  Finally, the focus group participants pointed to the importance of local energy codes set on a "local jurisdiction-by-local jurisdiction" basis as a critical driver impacting all building construction, whether for new facilities or improvements to existing buildings. Of particular importance is the adoption of the International Energy Conservation Code addressing energy efficiency requirements for new construction, additions, renovations and construction techniques.

- **Short term cost concerns holding back wider adoption, especially in green building by private developers.** The focus group participants, particularly those involved in green building design and construction, point to the fact that private developers are often reluctant to pay the additional costs for green buildings unless required. The reason for the

higher costs relates primarily to the cost of green materials rather than from higher design costs. Nevertheless, this cost concern by developers was generally viewed as reflecting very short-term thinking and not reflecting the lower costs of operating a green building over the long term. Too often developers make their profits by "flipping" their buildings once they achieve a high occupancy for a new building, so they are reluctant to pay for improvements that only provide benefits over the longer term. To have private developers decide to embrace green buildings will require having the green building standards be reflected in the sales price or the cost of insuring a building, which suggests that insurance companies and REITs will have a key role in emphasizing the importance of long-term cost savings from green activities.

- **Concern about Arizona's competitiveness for green manufacturing.** Many sectors of the green industry, particularly for manufacturing of renewable energy systems, is highly capital intensive. There is a concern among many stakeholders that Arizona's tax structure is not as favorable to highly capital intensive industries as other states and this may inhibit manufacturing job creation. In particular, interviewees cited the state's relatively high personal property taxes on equipment and the limited number of job creation incentives available from Arizona when compared with other states.

  Several focus group members suggested that the state's inability to compete for green manufacturing might argue for focusing on creating a stronger niche for Arizona in green R&D companies, with related focus on engineering, demonstration, and testing.

- **Concern about having "quality" work in solar installation.** Arizona's conditions are not typical in regards to solar installation because of the extreme high temperatures experienced in many parts of the state for prolonged periods of time. There was a concern that many solar installers were not adequately trained to properly install solar energy systems to address these high temperatures. Long term, the concern of several focus group participants was that faulty installations could limit the potential benefits from solar installation as well as create a public backlash against solar power.

The key result of these perspectives was that deployment of green technologies was as important a set of metrics of green development as Arizona's innovation in green technologies. In particular, even those focus group participants involved in innovation of green technologies saw a strong inter-relationship between a state's leadership in deploying green technologies as helping to fuel its efforts in innovation in green technologies. Not only does leadership in deployment offer insights into what innovations to seek, but it creates a business climate that promotes further innovation.

As a result of this input, Battelle has identified metrics to assess Arizona's position for future green economy development into two categories – innovation metrics and deployment metrics.

A. INNOVATION METRICS

The innovation metrics that Battelle developed in consultation with the Advisory Committee and focus groups includes:

- Federal research grants in green technology fields
- Publications in peer-reviewed journals on green technologies
- Patents generated on green technologies
- University technology transfer activities involving green technologies
- Federal Small Business Innovation Research grants awarded in green technologies
- Venture capital investments in green start-up and emerging technology firms

Below, the rationale, measurement approach and current level of activity for Arizona in each of these metrics are examined.

Research Grants

Why is it important?	How is it measured?
Research grants from federal agencies are highly competitive and sought after. The ability to win research grants reflects the quality of researchers and depth of researchers involved in advancing green technologies.	Battelle identified from leading federal agency websites the specific grant awards in recent years to Arizona-based researchers. These leading federal agencies included National Science Foundation (NSF), U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DoE).

What is Arizona's level of activity?

Battelle identified the following levels of activity and key highlights in federal research grants to Arizona researchers:

- 64 active NSF grants to university researchers in Arizona involving key terms related to the green economy across renewable energy, greenhouse gas reduction, energy efficiency and environmental protection and conservation. Among the leading grants were those involving:
  - Novel technologies for measuring soil moisture and its impacts on climate change.
  - New methods for integrated water and wastewater planning.
  - Sustainable infrastructures for energy and water supply.
  - Energy applications for semiconductor materials
  - Sustainability metrics related to construction operations
- 41 active USDA grants to university researchers in Arizona involving key terms related to the green economy across renewable energy, greenhouse gas reduction, energy efficiency and environmental protection and conservation. Among the leading grants were those involving:
  - Development of decision support tools to improve watershed management decisions
  - Development, management, restoration, and reclamation of arid and semi-arid lands
  - Evaluating the effects of grazing land conservation practices on watersheds
- Notable large DoE grants including:
  - Cyanobacteria designed for solar-powered highly efficient production of biofuels
  - Advancing development of sustainable, high-energy density, low-cost electrochemical energy storage batteries
  - Sustainable algal biofuels consortium (led by Arizona State University)
  - Advanced multi-functional energy storage (AMES) battery prototype

Publications

Why is it important?	How is it measured?
It reflects the depth of scholarly activity taking place in Arizona, based on acceptance of articles in peer-reviewed journals.	Specialized searches of publication titles and abstracts maintained by the Thomson Reuters Institute for Scientific Information by Battelle based on a detailed "green-related terms" query.

What is Arizona's level of activity?

- From 2007-2009 Arizona organizations and institutions published 248 "green-related" articles (constituting 2.3% of all publications with at least one Arizona author).
  - The articles were captured through a detailed "green-related terms" query.
- Increasing level of annual publication over these three years –
  - 67 articles in 2007
  - 78 articles in 2008
  - 103 articles in 2009
- These 248 articles were published in 126 different research journals and publications
- Academic publications included: Arizona State University (118), University of Arizona (81), and Northern Arizona University (18)

Key journals and number of articles	
Environmental Science & Technology	26
Journal of Power Sources	12
Water Research	11
Water Environment Research	8
Chemosphere	8
Biodegradation	7
International Journal of Hydrogen Energy	6

University Technology Transfer Activity

Why is it important?	How is it measured?
University technology transfer is the means for translating university research discoveries into commercial products, particularly as measured by licenses of technology to companies and by start-up companies formed.	Battelle solicited from each of the three research university in Arizona their technology transfer activities involving green technologies over the past three years.

What is Arizona's level of activity?

- Over the past three years, across Arizona's three research universities' technology transfer activities related to green technologies includes:
  - 16 licenses of green technologies were issued
  - 8 start-up companies were formed

Start-up companies based on AZ universities' technology	
Company	**Technology**
Arizona Synthetic Fuels, LLC (AZ)	*Synthetic Methanol*
Climatewise Solutions, LLC (AZ)	*Greenhouse Gas Consulting & Inventory*
Energy Materials Corp. (NM)	*Fuel Cell Membranes*
Fluidic Energy, Inc. (AZ)	*Utility-scale Advanced Battery System*
Heliae (AZ)	*Algae-based Biofuel*
REhnu, LLC (AZ)	*Solar Energy Concentrator*
Renascent Materials (AZ)	*Carbon Dioxide Sequestering Cement*
Solar Technology Research Corporation (AZ)	*Reduced-cost Solar Grade Silicon*

Patents

Why is it important?	How is it measured?
A measure of the generation of new ideas in the form of intellectual property. Patents include both industry and universities.	Specialized searches by Battelle using a detailed set of green search terms of U.S. patents using the Thomson Delphion patent database. Examine both inventors and companies acquiring patents that are based in Arizona since it reflects the full level of patent-related activities in the state.

What is Arizona's level of activity?

- From 2007-2009 Arizona "inventors" and "assignees" were part of 93 "green-related" patents
  - 78 patents with at least one Arizona inventor and 52 with both an Arizona inventor and assigned to an Arizona company.
- Arizona has had small fluctuations in year to year levels of patent activity in green technologies:
  - 36 patents in 2007
  - 27 patents in 2008
  - 30 patents in 2009
- These patents were spread across 44 different patent classes.
- These patents were spread across 64 different "assignees" including some not based in Arizona.

Key patent classes and number of patents	
Liquid purification or separation	16
Chemistry: electrical current producing apparatus, product, and process	11
Batteries: thermoelectric and photoelectric	5
Prime-mover dynamo plants	5
Synthetic resins or natural rubbers	4

Companies with 3+ "green-related" patents	
Sion Power Corporation (Tucson)	7
Arizona Public Service Company (Phoenix)	5
Medusa Special Projects, LLC (Tucson)	5
AdobeAir, Inc. (Phoenix)	3
Shell Oil Company (Houston, TX)	3

SBIR Awards

Why is it important?	How is it measured?
Federal Small Business Innovation Research awards are grants provided to small businesses for advancing the commercialization of innovative technologies in key topic areas of interest to the federal government. SBIRs are a measure of emerging companies with product development ideas in green economy.	Battelle reviewed all of the SBIR awardees in Arizona over the past three years to identify those that fall within green technologies.

What is Arizona's level of activity?

- From 2007-2009, 17 Arizona companies received 29 "green-related" SBIR awards, totaling just over $7 million.
    - 22 companies received nearly $2 million in Phase I funding and 7 companies received more than $5 million in Phase II funding
- Each year the value of SBIR awards to Arizona has increased, reflecting increasing successes in winning second phase awards, and the number of companies receiving awards has reached 9 per year for 2008 and 2009.
    - 2007: 5 companies and $1.3 million
    - 2008: 9 companies and $2.4 million
    - 2009: 9 companies and $3.5 million
- 4 companies accounted for more than half the number of awards granted and 80% of all Arizona SBIR "green" technology funding:
    - Burge Environmental, Inc. (6 awards, $2.4 million);
    - Materials & Electrochemical Research Corp. (4 awards, $1 million);
    - Diversified Energy Corp. (3 awards, $950 thousand); and,
    - Virtual Technology, LLC (2 awards, $1.2 million).

Venture Capital

Why is it important?	How is it measured?
A measure of emerging renewable technology companies	Based on venture capital funds invested in renewable energy companies. Data obtained from the Thomson VentureXpert venture capital base.

What is Arizona's level of activity?

Over the past three years, there have been no formal venture capital investments in green technology companies based in Arizona.

B. Deployment Metrics

The deployment metrics that Battelle developed in consultation with the Advisory Committee and focus groups include:

- Companies qualifying for ISO 14001 Certification
- LEED buildings in Arizona
- Energy Star Buildings and Manufacturing Plants
- Energy Efficiency Codes Adopted by Local Jurisdictions
- Solar Power Rebates

Below, the rationale, measurement approach and current level of activity for Arizona in each of these metrics are examined.

ISO 14001

Why is it important?	How is it measured?
ISO 14001 is a series of international standards that have been developed to incorporate environmental aspects into business operations and product standards, such as identification and evaluation of aspects and impacts, development of objectives and measurable targets, implementation of programs, and on-going monitoring and review.	Companies need to apply for and be certified to the ISO 14001 standard.

What is Arizona's level of activity?

From an investigation of the ISO website, Arizona is in the 2nd to top quintile of all states in number of companies that have received ISO 14001 certification. No other specific data is available.

LEED Certified Buildings

Why is it important?	How is it measured?
LEED is a third-party certification program and the nationally accepted benchmark for the design, construction and operation of high-performance green buildings.	LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. For each of these areas certification points are earned depending on the level of responsiveness to the criteria. Those certified buildings meeting the highest levels of performance garner a Platinum certification.

What is Arizona's level of activity?

- 102 LEED Certified buildings in Arizona out of 4,703 nationally
  - 6 Platinum
  - 41 Gold
  - 31 Silver

ENERGY STAR

Why is it important?	How is it measured?
ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy helping us all save money and protect the environment through energy efficient products and practices.	To qualify for the ENERGY STAR, a building or manufacturing plant must score in the top 25 percent based on EPA's National Energy Performance Rating System.

What is Arizona's level of activity?

- 139 Energy Star buildings in Arizona out of 9,976 nationally

Local Energy Codes

Why is it important?	How is it measured?
Energy codes adopted by local jurisdictions govern the construction standards that must be met for new construction, additions, renovations and construction techniques, and so energy codes are a critical driver for how building systems are put in place.	Battelle identified Arizona jurisdictions that have adopted the International Energy Conservation Code (IECC). The IECC is a baseline building energy code that states and local jurisdictions adopt to regulate the design and construction of new buildings. The IECC addresses all residential and commercial buildings. This code is updated every three years and the most current version is the 2009 IECC. The IECC addresses the energy-efficiency requirements for new construction, additions, renovations, and construction techniques. According to the Department of Energy, the International Energy Conservation Code (IECC) is adopted at the state or local level in 42 states plus Washington, D.C.

What is Arizona's level of activity?

- Statewide adoption of the IECC is limited to the Arizona Department of Health Services and all healthcare institutions (the 2006 standards).
- At a sub-state level, 7 of Arizona's 15 counties have adopted IECC, but of these:
  - None have adopted the 2009 standards
  - 4 have adopted the 2006 standards
  - 3 have adopted 2003 standards
- Numerous individual communities (34) have adopted IECC.

Solar Rebates

Why is it important?	How is it measured?
The adoption of solar power systems in residential buildings is largely dependent upon incentives provided to homeowners given the high upfront costs and long-term payback periods.	The best and most comprehensive examination of the solar rebates comes from the Database of State Incentives for Renewable Energy and Efficiency (DSIRE) program. This program tracks state and utility offered rebates around the country.

What is Arizona's level of activity?

Most, if not all, of Arizona's public utilities offer some level of solar (both electric and thermal) rebate program. These programs include:

- APS – Renewable Incentive Program
- SRP – EarthWise Solar Energy Incentive Program
- Sulphur Springs Valley EC – SunWatts Rebate Program
- TEP – Renewable Energy Credit Purchase Program
- Trico Electric Cooperative – SunWatts Incentive Program
- UES – Renewable Energy Credit Purchase Program

Additionally, the state also provides a tax credit capped at 25% of system cost up to $1000 (against state income taxes) making Arizona one of the leading states in the U.S. in terms of residential solar rebates.

However, issues still exist regarding the usage of these credits, related to a future with more abundant "net metering" options and "off-grid" potential.

VI. ARIZONA'S GREEN STRATEGIC OPPORTUNITIES

Bringing together the analysis of the emerging green economy and Arizona's overall position suggests that in several specific areas of the green economy Arizona is well-placed to grow. The following provides a brief primer to guide the thinking toward the development of these strategic areas. These specific areas of strategic opportunity for Arizona in the green economy include:

- Solar Photovoltaic (PV) Energy
- Solar Thermal Energy
- Wind Energy
- Biofuels/Biomass
- Energy Efficiency and "Green" Building Systems
- Water Efficiency and Management

Below for each of these strategic opportunity areas in the green economy for Arizona is a profile addressing:

- ***What it is?*** A descriptive overview of the general technical opportunity area.
- ***Key Global Trends***, including growth projections, key industry leaders and technology challenges that need to be addressed.
- ***Arizona's Current Position and Opportunities***, including a current status summary and a perspective on R&D activities and other metrics that enhance Arizona's potential in the area.

What is a somewhat unique aspect of these six green opportunity areas is that the lines of differentiation between them can often be blurry. This can lead to some difficulty discerning what companies and opportunities fit where. But more importantly, it should lead to a holistic approach to the development of both the companies and the workforce needed by these industry areas.

Solar Photovoltaic (PV) Energy

What it is?

Solar power is derived by converting energy from sunlight into heat or electricity. Solar energy technologies can be divided into two principal categories—photovoltaic (PV) and solar thermal systems. Photovoltaic cells alone or as an array convert sunlight directly into electricity. PV cells are semiconductors nearly always consisting of silicon crystals doped with impurities, a combination that in sunlight generates free electrons and thus an electric current (the photoelectric effect).

"Single-crystal," "multi- or poly-crystal," and "thin-film" (amorphous silicon) are the three main types of PV cells though it is not yet known which type will become the dominant technology. Crystalline cells currently account for most of the PV cell market. Thin-film solar cells do not absorb light as well as crystalline cells, but are thinner, smaller, and lighter weight. Lenses or mirrors can be used to focus sunlight onto a small area of PV cells, increasing the amount of sunlight absorbed. Antireflective coatings on PV cells also increase absorption.

Electricity produced by solar energy systems is either stored in batteries in an off-grid system or is fed into the electricity grid using through inverter technology. By the end of 2009, total global PV installations exceeded 21 GW (gigawatts) with the largest PV power plants located in Spain, Germany, Portugal, and the U.S.

Key recent trends and challenges in solar energy research include the continued drive to make solar cells cheaper and/or more efficient, developing new solar cell architectural designs, and development of new materials. With respect to materials research, some of the biggest inward investment wins announced in the clean technologies space by U.S. states recently have been in materials, with huge investments in polysilicon manufacturing plants (required as base materials for PV manufacturing).

Key Global Market Trends

Despite the challenging economic conditions present in 2008 and 2009, the global solar photovoltaic market has continued to make gains in installation. In 2009, new worldwide installations increased 20 percent over 2008 to reach 7.5 GW.[6] Growth in installations is anticipated to increase at a compound annual growth rate of 33.5 percent from 2009 through the middle of the next decade.[7] As a result, global installed capacity is projected to reach 152.2 GW in 2016, a seven-fold increase over 2009 cumulative installed capacity. Europe will continue to be a global leader in installed capacity, followed by Asia Pacific and North America. Solar photovoltaic production and installation is a $30.7 billion industry expected to increase to nearly $100 billion in 2019. Global employment in the solar PV sector was estimated to be more than 267.6 thousand in 2009, and has the potential to reach 2.2 million by 2019.[8]

[6] Marketbuzz, *"Solarbuzz Reports World Solar Photovoltaic Market Grew to 7.5 Gigawatt in 2009"* (June 2010).
[7] Frost & Sullivan, *Global Solar Power Markets* (2010).
[8] Clean Edge, *Clean Energy Trends 2010* (2010).

Unfortunately the historical and projected steady growth in solar PV installations does not equate to straightforward growth or expansion for suppliers. In 2009, suppliers experienced volatile market conditions with the next few years expected to be tumultuous should present conditions remain. According to GTM Research, in January 2009, leading PV manufacturers were operating at less than 20 percent capacity, but those same manufacturers had sold out of supplies by the end of 2009 spurred by an increase in German demand (2010). The global economic downturn resulted in oversupply and price drops which in turn led to revenue losses, layoffs, plant closings and acquisitions. Oversupply issues are not expected to reverse in the near future, with PV module supply expected to exceed demand by more than 25 percent per year from 2010-2013 (GTM Research, 2010). Suppliers will need to develop competitive cost structures in order to remain competitive. Manufacturers have already begun to realize production cost savings by outsourcing manufacturing to low-labor cost countries. In 2005, the majority of PV cells were produced by European and Japanese firms, while more than 50 percent of PV cells produced in 2009 were manufactured in China and Taiwan.[9] In the future, industry analysts are predicting increased commoditization of solar technology, further driving cost competitiveness, and firm consolidation across the value chain.

PV solar modules are constructed using one of three technologies: crystalline silicon, thin film, and concentrated PV. Of these, crystalline silicon comprises 81 percent of the market, followed by thin-film with 18 percent and concentrated PV consists of only one percent. The majority of PV solar cells (81 percent) and panels (78 percent) are produced using crystalline technology. Crystalline technology has advantages in energy conversion efficiency and reliability. Prior to the global recession, a polysilicon shortage contributed to the rise of thin-film's market share. In 2008, thin-film comprised 15 percent of production and increased to 22 percent in 2009. Already cheaper to produce, the polysilicon shortage and resulting price increase made thin-film technology even more attractive. Although less efficient than crystalline technology, thin-film has lower material and production costs and is better suited for curved, glass, and plastic surfaces. In addition, thin-film is better suited than its crystalline counterpart for use in environments with sub-optimal light conditions. Thin-film will likely continue to grow in market share – up to 30 percent by 2013 – however, other technologies, such as amorphous silicon, will own an even greater share of the market.[10]

The solar industry as a whole is largely driven by government incentives. Changing government budgets will impact the incentive structure of many governments, affecting the solar market's landscape. The largest shift will most likely be the slowing of Germany's installations due to feed-in tariff cuts set to begin in the second half of 2010. Italy is also expected to experience a decline in installations as a result of cuts in feed-in tariffs. Reductions in installations as a result of fewer incentives are anticipated to be offset by falling production and installation costs.

Key global industry leaders in solar PV include: First Solar, Suntech Power, Ja Solar Holdings Co., Sharp Electronics Corp., Yingli Green Energy Ltd, SolarWorld AG, Q-cells SE, and Sunpower Corp.

[9] EE Times Europe, "*Global Solar PV Cell Production Grew 51 Percent in 2009"* (2010).
[10] GTM Research, *2010 Global PV Demand Analysis and Forecast* (2010).

Arizona's Current Position and Opportunities

Beyond the headquarters presence of thin-film PV manufacturer First Solar, Arizona is home to key operations of Global Solar Energy, Inc., Kyocera Solar's U.S. headquarters, SOLON Corporation, and Schletter. Given the amount of sunlight available to Arizona residents, the state has developed one of the country's largest contractor, installation, and service infrastructures accounting for more than 75 (though mostly small) firms. This installation infrastructure is further enhanced by the significant utility-led rebate offerings for both residential and commercial installation of solar electric systems (though there is some concern about the usefulness of income tax related incentives on the substantial retiree community in the state).

The opportunity for Arizona should lie in the intersection between an advantageous "sunlight" position with a substantial semiconductor industry and research infrastructure.[11] Currently, however, significant employment from PV technological development and manufacturing efforts has not materialized in Arizona. This may be beginning to change as some limited "innovation" activity in the solar PV space is found within the metrics examined. Two new companies, REhnu and Solar Technology Research Corporation, both with strong state and state university ties, have established operations in Arizona. Both are taking unique approaches to improve the capacity and efficiency of solar PV systems.

Arizona also offers a unique "test bed" context for solar PV development and installations, and in fact this concept on a "utility scale" level is being pursued within the University of Arizona's TechPark SolarZone. Given the open land available within the state it is well positioned to host substantial utility scale solar operations (both solar PV and solar thermal). Combining a fairly robust residential customer base, with a sometimes extreme solar climate (the combination of substantial sunlight and extreme temperatures) puts Arizona in the position to capitalize on efforts to improve and enhance solar PV efficiencies and durability and to develop more "residential-friendly" solar PV technologies including small scale tracking capacity, better energy storage options, and building-integrated solar technologies (such as Dow's recently announced solar shingles). This opportunity becomes even more prominent if federal legislation, such as the 10 Million Solar Roofs Bill or other similar measures, end up becoming law.

[11] There is a substantial overlap in the underlying materials physics between semiconductors and solar photovoltaic materials. In fact, the North American Industry Classification System includes them both in NAICS 334413.

Solar Thermal Energy

What it is?

Solar thermal systems use solar energy to generate heat or thermal energy. These systems can provide heat or hot water for buildings or industrial processes or generate electricity by operating heat engines or producing steam to spin electric turbines in solar thermal electric power plants. Three types of thermal collectors vary in their temperature and subsequent applications—low, medium, and high temperature. Low temperature collectors are flat plates which are used to heat swimming pools or provide space heating or hot water; medium are used for hot water in commercial or residential buildings or drying construction wood or food; and high temperature use mirrors or lenses to concentrate a large area of sunlight into a single beam, converting this into extremely high heat and then into electricity via a conventional turbine-based power plant. These systems typically possess high solar-to-electric conversion efficiencies, and some store thermal energy for use during low-sun periods.

Among a range of technologies, the dominant types are parabolic troughs, concentrating linear fresnal reflectors, the Stirling dish, and the solar power tower. Each varies in its size, land use, reflector lens shape, working fluid heated, and method of tracking sunlight. Non-concentrating systems do not use lenses or mirrors to focus sunlight and thus are less efficient thermodynamically. As with photovoltaic solar cells which directly convert sunlight into electricity, technology challenges and research trends in solar thermal energy focus on technologies that will continue to lower the cost and/or improve the efficiency of systems. Technological challenges and opportunities include materials, lens and mirror shapes, solar tracking software and systems, and storage devices.

Key Global Market Trends

The solar thermal energy market can best be understood by examining two distinct subsets.

The solar heating, or direct use, category refers to technology that captures heat from the sun to heat or cool water. This technology is most commonly used for heating water for swimming pools and providing hot water for residences, but can also be used for heating and cooling space in both residential and commercial buildings. Solar thermal collectors currently produce more energy than wind power or solar PV; in 2009 there were 174,000 MW of solar thermal collectors installed compared to: 147,000 MW of wind and 17,000 MW of solar photovoltaic (PV) capacity.[12] Solar thermal systems utilize a lower level of technology than concentrated solar power or solar PV, are relatively inexpensive to produce, and have no cost to use once installed.

In 2009, the residential and commercial solar thermal technologies market was worth approximately $8 billion globally.[13] However, strong demand is expected to stimulate this market to a compound annual growth rate of 19.8 percent from 2009-2014, to reach an estimated global value of $20 billion. Growth in the water heating segment will dominate the market accounting for

[12] ABS Energy Research, *Solar Thermal Power* (2010).
[13] BCC Research, *Global Markets for Residential and Commercial Solar Thermal Technologies* (2009).

over $19 billion of the industry's worth in 2014. Air heating is anticipated to increase its market value from $62.5 million in 2009 to $92 million in 2014.

Solar thermal systems make sense for regions with high energy costs or a lack of infrastructure. In developing countries relatively inexpensive solar thermal systems are being installed in areas without an energy infrastructure similar to the way cell phones were adapted in developing countries without traditional telephone infrastructure.[14]

In developed countries, solar thermal systems are being adapted because of incentives or mandates passed in an attempt to reduce the environmental impact of traditional energy generation and dependence on foreign energy resources. World-wide, the largest market by far for solar heating technology is China. In 2008, China had 87.8 GW of installed capacity. Europe followed with 28.5 GW, and the U.S. and Canada combined reached an installed capacity of 15.1 GW. Together, these three regions account for 86 percent of the entire market.[15] Uses for solar thermal energy vary widely by country. China, Europe and Japan rely on solar thermal systems to provide hot water and space heating. By comparison, the U.S. and Canada solar thermal systems are predominantly used for heating swimming pools. Spain, Austria and Germany use solar thermal technologies for a multitude of uses including: hot water preparation, space heating single and multi-family houses and hotels, air conditioning and cooling, and industrial applications.

Key industry leaders in the solar heating sector include: GREENoneTec, TiSUN, SOLID Energy, Viessman, Bosch Thermotechnik, Ezinc, Himin Solar Energy Group; Haining Baoguang Heat Collection Tubes Co., Ltd., and Beijiing Sunda Solar Energy Technology Co.

Concentrated solar power (CSP) differs from solar heating technology in that it uses solar energy to generate heat and electricity. CSP plants are typically located in regions with low cloud coverage, high solar density, and large areas of land available for development. CSP energy is less expensive than PV energy, costing 12-19 cents per kWh compared to 15-30 cents per kWh for solar PV. However, CSP is still an emerging technology and therefore is largely dependent upon government support.

The largest markets for CSP systems are the U.S. and Spain. In 2009, the U.S. accounted for 100 percent of the CSP system installations in North America, while Spain accounted for 95 percent of Europe's total installed capacity. Currently, the world's largest solar power plants use concentrating solar thermal technologies, such as the Solar Energy Generating Systems plant in California's Mojave Desert with a capacity of 354 MW.

Globally, CSP installations are projected to increase at a compound annual growth rate of nearly 50 percent from 2009-2016, increasing from a cumulative installed capacity of 817 MW in 2009 to 13,679 MW in 2016.[16] Yet, substantial growth is forecast as over 10,800 MW of capacity are currently in some stage of development. Much of this growth will continue to be led by the U.S. (worth as much as $70 billion) and Spain due to resource and policy support, but Greece and Italy are also projected to show a substantial increase in installed capacity.

[14] Grist, "*On Rooftops Worldwide, a Solar Water Heating Revolution*" (2010).
[15] International Energy Agency, *Solar Heat Worldwide* (2010).
[16] Frost & Sullivan, *Global Solar Power Markets* (2010).

As with any new technology, CSP systems must overcome many challenges before it will realize wide-spread acceptance including upfront capital costs for installation and issues related to the transmission infrastructure. In addition, permitting procedures tend to be rigorous and time-consuming. As Santiago Seage, CEO of Abengoa Solar stated in regards to the two and a half year permitting phase of the Solana Concentrating Solar Power project in Gila Bend, Arizona, "that's too long…one of the weaknesses of working in the southwestern states."[17] Lastly, current CSP technologies require large amounts of water for wet cooling – a major obstacle for the desert areas best suited for CSP plants, or use dry cooling methods that increase capital costs and decrease performance. Despite these challenges, CSP technology remains promising for delivering efficient, cost-effective renewable energy.

Key industry leaders in the concentrated solar power sector include: Solar Millenium AG, BrightSource Energy Inc., eSolar Inc., Ausra Inc. (recently acquired by Areva), Abengoa Solar, ACCIONA Solar Power, and Stirling Energy Systems.

Arizona's Current Position and Opportunities

Arizona industry base in solar thermal is fairly limited with the largest single "manufacturing" firm being Hydro Aluminum's Solar Solutions branch (which makes aluminum structures for concentrated solar power technologies). Additionally, Arizona is home to Sterling Energy Systems a leading manufacturer of concentrated solar power systems. However, beyond these two companies much of the solar thermal activity in Arizona is built around the installation of solar water heating systems.

The environment provides the biggest opportunity for Arizona as it has significant sun hours and vast amounts of undeveloped land. Additionally, the overall temperature is less an issue with solar thermal technologies than existing PV technologies. However, as described above, the permitting to access this land can be a challenge. This may be improving as the Bureau of Land Management has instituted a "Fast Track" process to improve the speed of issuing permits for these developments. In fact one of the first projects receiving federal permits through this effort is the NextEra-Sonoran Solar Project – a 375 MW parabolic trough in Maricopa County.

[17] Greentech Media, "*$1.45 Billion Loan Guarantee for Abengoa CSP Plant*" (2010).

Wind Energy

What it is?

Wind energy generates electricity by converting the mechanical energy of rotating turbine blades into an electrical current. Wind energy is used in both large- and small-scale applications. Large-scale applications such as wind farms produce electricity for the grid and may include storage capacity to compensate for variable power output. Small-scale applications such as individual small wind turbines provide electricity for isolated or off-grid locations and may also operate in conjunction with storage systems, often batteries.

Technical factors such as wind speed and variability, climate, and proximity to the grid all must be considered when sitting wind turbines. Other factors include aesthetics and the potential threat to birds. Turbines can be installed on land or offshore (i.e., in a lake or sea). Onshore turbines may be more productive the closer they are to a shore, as shores tend to be windy owing to the differential heating and cooling of land and water. Offshore wind turbines are seen as less obtrusive than onshore and may generate more power as the wind speed over open water is significantly greater than it is over land. However, offshore turbines are more difficult and costly to install and maintain.

Recent large-scale applications typically rely on wind turbines rated between 1.5 MW and 3.0 MW, with the average wind turbine in the U.S. being 1.6 MW-at least twice as powerful as the average wind turbine installed in 2000. These new installations range in height from 330 to 490 feet. Several companies are currently working to develop a 10MW turbine. Beyond these large, utility-scale wind turbines are much smaller installations suitable for power a single residence or company. The American Wind Energy Association (AWEA) defines these small wind turbines (SWTs) as those with a power capacity of 100 kW or less.

Technology trends, challenges and opportunities in wind energy include overall scalability; the viability of SWT's for residential, commercial and other small-scale applications; installation costs and challenges particularly with respect to offshore farms; energy storage and grid transmission.

Key Global Market Trends

Global wind power generation capacity reached 159 GW in 2009, although wind and wind speed is not consistent and a wind farm's "production" never fully reaches "capacity." Aided by government subsidies, several European countries have significant shares of total electricity generated by wind power including Denmark, Portugal, Spain, Germany, and Ireland. Total installed capacity is currently greatest in the U.S. followed by Germany, China, Spain, and India.

The global wind power market is projected to experience continued growth as the international community attempts to rebuild aging energy infrastructures and meet growing energy demand in the midst of the economic recovery. The Global Wind Energy Council forecasts installed global capacity to increase to more than 330 GW by 2013. According to a recent publication by Clean Edge, Inc, the wind power market will grow from $63.5 billion in 2009 to $114.5 billion by 2019.[18] Emerging markets in China and India coupled with potential growth in leading wind power

[18] Clean Edge, Inc., *Clean Energy Trends 2010* (March 2010).

generating nations such as the U.S., provide opportunities for wind power to play a significant role in the future of renewable energy generation. In 2009, the U.S. increased wind capacity to 28,162 megawatts, with an additional 3,962 MW under construction. Germany and Spain, the second and third leading producers of wind power in 2008, possessed a total capacity of 23,903 MW and 16,740 MW, respectively. However, the greatest progress from 2008 through 2009 can be found in China. In 2008, China added 6,298 MW of wind power capacity and had a total capacity of 12,210 MW.[19] By the end of 2009, China accounted for more than 33% of all new installations and became the global leader in new installation, adding an additional 13,000 MW of wind power capacity.

The regulatory environment and governmental incentives have played an integral role in the burgeoning global wind power sector. In the U.S., the American Recovery and Reinvestment Act extended tax credits for renewable energy and the Department of Energy distributed $50 million for research and development in wind technologies. Offshore wind farms are becoming common in Europe and are becoming increasingly realistic in the U.S., as turbine manufacturers such as GE are introducing direct drive turbines which minimize maintenance costs and are equipped with tower elevators that make the towers more accessible for maintenance. Growth is not limited to large wind applications, as interest is also increasing in small wind turbine applications. Important to both the U.S. and Arizona is that according to the AWEA, two-thirds of all small wind systems sold around the world in 2009 (42.5 MW) were produced by American manufacturers.[20]

Although the global market for wind power has found increased demand, given the capital intensity of large wind operations the global economic crisis halted numerous potential projects. Transmission and distribution (T&D) also pose challenges for the wind power sector. As wind farms tend to be located in remote regions, a shortage of transmission lines may threaten growth within the industry and will require upward of $60 billion in new transmission lines.[21] Overly restrictive zoning laws and poor permitting may also discourage potential customers of small wind turbines for residential-use.

Key industry leaders in the wind turbine industry include: Vestas Wind Systems A/S, GE Energy, Sinovel, Suzlon Energy Limited, Gamesa, Enercon, and Siemens.

Arizona's Current Position and Opportunities

Arizona's "wind" generating capacity is on the low side in terms of statewide continuous wind speed, nonetheless from a corporate perspective Arizona is home to one of the largest and most respected small wind turbine manufacturing companies, Southwest Windpower in Flagstaff, which continues to grow and expand. Arizona also has a number of firms involved in the wind turbine supply chains including TPI Composites, Copper State Bolt & Nut, and Valley Forge and Bolt. A number of new wind turbine technology companies are also being established in the state.

[19] Plunkett's Research, LTD. *Guide to the Alternative and Renewable Energy Industry* (2010).
[20] American Wind Energy Association, *AWEA Small Wind Turbine Global Market Study* (2010).
[21] Frost & Sullivan, *North American Wind Power Plant Service Market* (February 2009).

Biofuel/Biomass Energy

What it is?

Biomass is a broad term referring to an "organic feedstock" or "biological material" used to create fuel, power, or products (plastics and chemicals). Biomass encompasses a wide spectrum of materials including: wood and forest residues, dedicated energy crops, food crop residues, municipal landfill waste, livestock waste, and wood waste such as wood chips and sawdust. Biomass as a renewable energy source involves converting these materials into fuel or electricity through various technologies including direct combustion, anaerobic digestion, rapid thermal processing, and gasification. The market for biomass is driven by environmental concerns as well as the anticipated long-term increase in energy costs and the need for energy independence.

Paper mills are the largest current producers of biomass power, generating electricity via direct-fired burning of pulp waste to generate steam that drives a turbine. Another leading biomass energy source for electricity is methane gas captured from landfills or other sites where biomass decay occurs naturally (e.g., manure-rich dairy farms) or can be promoted by using certain bacteria that decompose organic matter. Methane is the primary ingredient of natural gas. A key advantage of methane as an energy source is that it simultaneously reduces the amount of methane (which is considered to be a greenhouse gas) that is released into the atmosphere.

Ethanol produced from fermenting the starches and sugars in corn, wheat, sugar cane, and other sources have been used for several decades, and are considered first generation biofuel technology. Cellulosic biofuels, considered second generation technology, eliminate the food vs. fuel conflict by creating biofuel from non-food sources such as wood, switch grass, crop residues, and forest waste. In addition, cellulosic biofuels have a higher energy content and increased potential to reduce green house emissions than first generation technologies. Currently, second generation biofuels are expensive to produce with the transportation costs of moving the biomass feedstock remaining a challenge. Third generation biofuels are those created using algae as a feedstock. Biofuel derived from algae is an emerging technology that has yet to be proven on a commercial scale. However, algae have the potential to create 30 times more energy per acre than other types of biomass, and can be harvested from marginal lands or water. Algae use common water pollutants as a nutrient source, thereby minimizing harmful environment effects, making algae biofuels even more attractive. Issues remain concerning the ability to economically produce enough algae to create fuel on a large scale and the cost-effective harvesting of algal feedstocks.

Ethanol is most often blended with gasoline to create a fuel with fewer green house gas emissions. Biodiesel is produced through an altogether different method (transesterification) using crops, waste, or microbes with high oil content.

Unlike other renewable energy assets—solar, wind, tidal, hydro and geothermal—biomass has the unique capacity to generate energy and serve as a sustainable, abundant, flexible and adaptable feedstock for manufacturing applications. For those regions that are rich in biomass, opportunities abound for economic development and growth built around a new biomass processing industry paradigm producing bio-based materials and products.

Technology trends, challenges, and opportunities around biomass include: the strong focus of R&D around biofuels and cellulosic materials as feedstock in particular; closed-loop biofuel production plants; pretreatment of source matter; conversion technologies and their efficiency; consolidated bioprocessing (fermenting biomass without adding enzymes); "green" biodegradable/bio-based materials; and transportation, storage, and other infrastructure issues.

Key Global Market Trends

Global capital investment in the biomass market is projected to reach between $41 billion and $83 billion by 2030.[22] Electricity created from biomass is anticipated to be valued at $53 billion by 2020. Biomass power plants vary greatly in their form, ranging from small family owned stoves to large utility companies using co-firing methods to generate power. Although biomass power is anticipated to grow over the coming decade, it will offer the least amount of installed renewable energy capacity globally, when compared to wind, solar, and hydropower.[23]

Currently Brazil, the U.S. and China are the largest producers of biofuels. The world-wide biofuel market was valued at $60.6 billion in 2008, and is expected to increase to $77.1 billion by 2013.[24] First generation biofuels will continue to dominate the biofuel market through 2013. Ultimately, further growth in the biofuel industry will be driven by the introduction of commercial scale second and third generation biofuel production. In the near-term, growth in the biofuels industry (through conversion technologies) will likely lag biopower (direct-fired) and bioproduct markets.

Many countries are investing in research on how to overcome these challenges, including the U.S. The U.S. Department of Energy recently announced an $85 million stimulus initiative to invest in the development of algae and advanced biofuels compatible with existing infrastructure. Frost & Sullivan forecast that commercialization of algae based biofuels will take place by 2015.[25]

Biobased products, mainly chemicals and plastics, are poised for significant growth in the coming years. The market for biobased plastics will grow 13 percent annually from 2010-2014.[26] Biobased plastics are being used in a wide variety of products like bathtubs, eyeglasses, food storage, automobile interiors, and packaging. As consumers become increasingly environmentally conscious, producers are meeting their demand for environmentally friendly products. In addition, plastic producers are investing in biobased plastics to offset anticipated increases in petroleum costs. Biochemicals also have the potential to realize substantial growth in the next fifteen years. Based on current estimates, biochemicals account for 3-4 percent of total global chemical sales. Even under the most modest circumstances, experts anticipate biochemicals accounting for 7 percent of global chemical sales. Under the most favorable conditions biochemicals could account for 17 percent of the market.[27]

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[22] Pike Research, *Biomass Markets and Technologies* (2010).
[23] Frost & Sullivan, *Outlook for the Power and Energy Industry* (2010).
[24] BCC Research, *Liquid Biofuels: The North American Market* (2009) and *The Market for Liquid Biofuels Outside North America* (2009).
[25] Frost & Sullivan, *North American Biofuels Market* (2009).
[26] PRWeb, "*Bioplastics Market to Grow 13% Annually Through 2014*" (2010).
[27] ICIS, "*The growth of bioplastics*" (2010).

Key industry leaders in the biomass industry include: Valero, POET, Archer Daniels Midland, Hawkeye Renewables, Abengoa Bioenergy, Gevo, DP CleanTech, Metso, and Petro Sun Biofuels.

Arizona's Current Position and Opportunities

Like many other states, Arizona has seen some ethanol development (e.g., Pinal Energy) and has some opportunities related to woody biomass (e.g., Forest Energy Corporation). Arizona, however, is actually an unexpected home to a significant amount of algae-based biofuel development, with much of it related to research performed in Arizona State University's Laboratory for Algae Research and Biotechnology.

As part of its on-going research efforts, this lab recently garnered two significant DoE research grants to further its research into algae-based biofuels. This research is also leading to commercial opportunities. At least two companies, PetroAlgae LLC (which has subsequently moved to Florida) and Heliae Development LLC (located in ASU's SkySong in Scottsdale) have been formed based upon this research. Additionally, Diversified Energy, located in Gilbert, is also engaged in algae-related technology development including both the use of algae as a fuel feedstock and in the development of an algae growth system.

Energy Efficiency and "Green" Building Systems

What it is?

"Energy efficiency" has been in the mindset of building owners since the 1970's. Within the last decade a renewed public interest in energy efficiency (as energy prices have soared) coupled with a movement toward improving the quality of our physical surroundings has led to the concept of "green buildings." The green buildings and sustainable design and construction sector is newly evolving and aims to create new or modify existing structures with materials and designs that are energy and resource-efficient, environmentally responsible, and healthy for occupants through the building's entire life-cycle. To achieve these aims, firms in this sector use materials and other inputs that are:

- Manufactured in a sustainable fashion that is resource efficient, conserves energy and water, and minimizes waste and pollutants;
- Manufactured from recycled, salvaged, waste, or readily renewable inputs;
- Beneficial to the built environment by conserving or reducing the use of energy or water and reducing or eliminating indoor pollutants; and
- Largely recyclable at end of their useful life.

The primary goals of green building are to impact the following in a sustainable manner: *energy efficiency/reduction* with examples including use of highly efficient insulation and windows, design to maximize solar exposure, and onsite renewable energy generation; *water efficiency* with examples including minimized use and maximized re-use using low-flush toilets and shower heads, and smart use of gray water; *materials efficiency* with examples including those materials that are locally sourced, recycled, and/or made from rapidly renewable materials; *waste reduction* with examples including reducing the amount of construction or demolition materials sent to landfills.

The reduction or elimination of indoor pollutants combined with efforts in Indoor Environmental Quality (IEQ) provides the basis for "healthy buildings." Therefore, by their nature, green building technologies and products improve or, at worst, are neutral toward, indoor air/environmental quality. Historically, building materials including exterior/ structural materials, carpets, paints, ceiling tiles, and furniture often emit particles or volatile organic compounds (VOCs) into the indoor environment or potentially leach toxic elements into the outdoor environment. The green building segment is targeted at changing these outcomes for overall environmental improvement and thereby maintaining the health and productivity of a building's occupants.

Unlike other industry-technology segments, much of the structured development of this segment has occurred due to the advocacy, education, policy development, and standards development of a nonprofit organization—the U.S. Green Building Council (USGBC). The USGBC is composed of leaders from every sector of the building industry and works to promote buildings that are healthy places to live and work and building practices that are environmentally responsible and profitable. The USGBC's LEED® (Leadership in Energy and Environmental Design) Green Building Rating System is the nationally accepted standard for green buildings. Beyond LEED, other standards programs such as the EPA's ENERGY STAR, the Environmental Institute's GREENGUARD

certification, or other indoor air requirements are also integral in developing green and healthy buildings.

Many of the technology challenges, drivers, and opportunities associated with the green building sector relate to cost as new materials, appliances, and on-site renewable energy are expensive. This is mitigated, however, over the building's life-cycle as up-front costs are in turn often more than paid for over the building's useful life. Costs are offset by money saved through energy efficiency and decreased energy bills, as well as greater worker health and productivity. Recent innovations in financial models are only beginning to help green building owner occupants to amortize more of the up-front investments that would be offset by anticipated operational cost savings.

Key Global Market Trends

According to US EPA's ENERGY STAR certification program, Americans purchased over 300 million ENERGY STAR certified products in 2009, with a cumulative total of approximately 3 billion products purchased since 2000. The majority of purchased ENERGY STAR certified products were household electronics. The market for energy efficient products in the United States, especially for lighting, will continue to grow due to federal regulations including the phase out of incandescent light bulbs by 2012, providing opportunities for producers of compact fluorescent lamps (CFL) and other energy efficient lighting technologies.[28]

In 2009, the global green building industry totaled over $553 billion according to the *4th Annual Green Building Survey*.[29] Within this building activity more than 100,000 new homes were constructed to meet ENERGY STAR guidelines in 2009.[30] However, the market for green building, especially the certification of green buildings and for commercial green buildings, appears to be threatened by current real estate market conditions. As funding for real estate projects has stood at a standstill throughout the Great Recession, developers are less likely to pursue more costly projects such as LEED certified buildings.

The *4th Annual Green Building Survey* also showed that green building costs varies according to circumstances such as the experience of teams, local codes that may require a minimum performance achievement level of LEED Silver, and the type of building (hotels and hospitals tend to be more costly than buildings for office or residential use). The survey also found that while overall support for green building remained fairly stable between 2007 and 2009, at 96.8% and 92.3% respectively, support for LEED certification has slipped. In 2007, 77.4% of those surveyed believed it was worthwhile to obtain LEED certification. In 2009, 61.7% respondents agreed. Explanations for the decline in support for LEED certification include the current real estate climate and the emergence of new certification programs including Green Point Rated by Build it Green.

Barriers to enter the green building market remain. A focus group of 50 leading architects, developers, brokers, bankers and equity providers cited the following as barriers for green building: lack of information regarding costs and benefits for green products, communication shortfalls

[28] Frost & Sullivan, *Energy Technology Regulations and Policy Trends for Energy Efficiency*, 2010.
[29] Allen Matkins, CTG, Green Building Insider, *4th Annual Green Building Survey*, 2010
[30] United States Environmental Protection Agency, *ENERGY STAR Overview of 2009 Achievements* (2010).

including the lack of demand by consumers for energy efficient products over space and finishes, lack of motivation for developers and existing owners to invest long-term and install more expensive energy efficient products that will benefit future owners, funding issues, and a lack of expertise in small communities that may lengthen time frames for development. Recommendations for reducing current barriers for green development include altering existing codes and ordinances to promote green building, and include maintenance and energy saving costs when comparing prices.[31]

While commercial buildings are seen as a major factor in global warming and resource requirements, the market for green certified commercial real estate has been especially vulnerable to the recent economic downturn. According to the US EPA, energy use in commercial buildings accounts for 17% of greenhouse gas emissions in the United States and costs over $100 billion per year.[32] Yet, the vacancy rate for LEED certified, 500,000 to 1 million square feet, multi-tenant, Class A office space for the second quarter of 2010 was approximately 22%. The average vacancy rate for all Class A office space between 500,000 to 1 million square feet was about 17%.[33] Expanding the market for green building will mandate stronger code enforcements from local governments, incentives for developers and existing owners to pursue green projects, and informing consumers about the importance and benefits of green building.

Industry leadership is highly dependent on the segment of energy efficiency or green building systems and components. Needless to say many U.S. "household name" manufacturers are among the leaders including CertainTeed, Johns Manville, and Owens Corning (insulation and other building products), Anderson, Jeld-WEN, and Pella (windows and doors), and Rheem, Goodman, Lennox, and Nordyne (residential HVAC systems).

Arizona's Current Position and Opportunities

In the development of green buildings, Arizona has an active base of architects and construction companies involved in green building activities, including three local chapters of the U.S. Green Building Council which sets the standards for LEED (Leadership in Energy and Environmental Design) green building certification. To date, there have been 102 LEED certified buildings constructed in Arizona and 139 buildings and manufacturing facilities that qualify for the U.S. EPA/U.S. DoE Energy Star designation.

But, at the national level, Arizona is not a leader in green building development. Arizona's level of LEED certified buildings and Energy Star designated buildings is only 2.2% and 1.4% of the national total, respectively. One reason for Arizona not being among the national leaders is state and local government overall policies towards advancing green building development. While there is in place an executive order advancing LEED certification at the state level, there has been no state funding available to move LEED building development forward. Furthermore, Arizona is not active in advancing a statewide energy efficiency code, with its current efforts limited to the Arizona

[31] Choi, Christopher, "*Removing Market Barriers to Green Development: Principles and Action Projects to Promote Widespread Adoption of Green Development Practices"*, Journal of Sustainable Real Estate, vol. 1, num. 1, (2009)
[32] United States Environmental Protection Agency, "*EPA Issues Second Annual Ranking of U.S. Cities with the Most Energy Efficient Buildings: List Shows Continued Growth in Saving Money and Energy*" (2010).
[33] Miller, Norm, *Does Green Still Pay off?*, 2010

Department of Health Services and healthcare institutions. At the local level, only seven of Arizona's fifteen counties have adopted energy efficiency codes, along with 34 individual jurisdictions. The private sector in Arizona is also not generating significant focus on green building development. Discussions with architects and executives from construction companies pointed out that private developers in Arizona do not see green buildings as offering a market differentiator and are often reluctant to pay the additional cost for green buildings, especially in a tight economy.

One area of green building development where there is a significant base of activity identified in Arizona is in the production of building products and materials used in green buildings. Arizona has 116 establishments, employing 2,234 workers, in energy efficient building products and materials and another 18 establishments, employing 673 workers that produce building products and construction materials designed to improve the environment.

Water Efficiency and Management

What it is?

Across the globe and within the U.S. clean water is an increasingly scarce commodity. Some commentators are noting that the economic opportunities in water-related technologies approach, or perhaps even exceed, clean energy. Everybody on the planet needs water, agriculture and livestock production consume vast quantities of water, and industry represents 60 percent of water use in industrialized nations according to the UN. Clean water is a core input to an incredible array of products and is required in large-volumes for many manufacturing processes. The U.S. EPA, for example, notes that manufacturing one ton of steel requires 60,000 gallons of water and the production of one automobile requires 40,000 gallons.

Ensuring adequate supplies of available clean water clearly requires efficient management practices. Water efficiency seeks to focuses on reducing waste while not restricting use. This applies to both residential and commercial water users and identifying ways in which to reduce water waste and make choices that emphasize water-efficient products and practices.

The market for water efficiency products/practices spans residences, manufacturers, farmers, and utilities with both common and unique applications for each type of water consumer.

Further business activity that involves water as a resource or its supply and consumption as a service or product consists of the following four sectors:

- Water utilities—entities that collect water from surface or ground sources, purify it, and distribute it to water consumers and their residential, commercial, industrial, and agricultural customers
- Wastewater treatment and water reuse/recycling facilities
- Water distribution and purification equipment and chemicals companies
- Water systems engineering and consulting companies.

Challenges and opportunities with respect to water efficiency entail not only new technologies but also education and consulting around smart practices. For example, many manufacturers need advice on identifying ways to reduce water waste due to leaks and inefficient processes such as continual spraying on production lines, retrofitting existing plant equipment to increase efficiency, and re-using wastewater. For utilities, these challenges involve universal metering, managing water-loss in the system, tamper-proof fire hydrants, equipment upgrades and retro-fits, and modifying billing software to track effectiveness of water saving promotions.

Key Global Market Trends

Management of water resources is becoming an increasingly fundamental concern for communities around the globe. Water scarcity will affect approximately 50% of the world's population by 2030 and, in the United States, 36 states will face water shortages by 2013.[34] Due to looming effects of climate change, water utilities must find ways to maximize efficiency by reducing energy usage for treatment and processing, and minimize water surrendered to leaks and water main breaks in aging infrastructures.

Water management systems have responded by implementing information technologies to collect and monitor data that may alert systems of potential leaks or main breaks. According to a survey of 103 public and private leaders conducted by IBM, although 80% of respondents indicated an increase in information over the course of the past five years, 63% said providers lacked the needed systems to handle the information.[35] The private sector has begun to capitalize on the opportunity: Venture-backed Israeli start-up TaKaDu developed a mathematical algorithm that analyzes collected data and predicts leaks and system inefficiencies and now provides services to water utilities around the world.[36] The US EPA's WaterSense program offers certification for water efficient toilets, bathroom sink faucets, products for new homes, and showerheads.[37]

In the agriculture industry, IBM reports that sensors are managing air quality and soil moisture data in order to optimize irrigation. Smart water meters continue to enter the market. These sensors, equipped with automatic meter reading (AMR) technology that sends information directly to a central database, can help reduce utility costs for travel and in-person readings. Smart water meters, similar in concept to smart meters for the electric grid, collect consumption and time-of-purchase information that allow service providers to adjust pricing to better align with demand. According to Pike Research, the global market for smart water meters will expand from 5.2 million installed in 2009 to 31.8 million by 2016. Yet, key challenges including labor union resistance to AMR, and a highly fragmented water utility market (there are approximately 52,000 water suppliers in the United States) will impact the overall level and speed of deployment.

Recycling systems for gray water, household wastewater from washing machines, dishwashers, faucets, bathtubs, and shower units, and rain harvesting products have become increasingly available in the market. According to the Department of Energy, typical gray water recycling systems, although expensive, have a return on investment rate of approximately ten years.[38] Gray water recycling systems are primarily used for irrigation purposes and flush water for toilets. Rain harvesting products include rain barrels, which capture and store rain water from roofs, are typically used on residential properties. Driven by rising energy costs and world population, aging infrastructure and droughts caused by climate change, improved water efficiency and management will require sweeping infrastructural upgrades and improved data management.

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[34] Pike Research, *Smart Water Meters* (July 2010).
[35] IBM, *IBM Water Management Pains Report: Survey Findings and Recommendations* (January 2009).
[36] Venture Beat, "TaKaDu Has VCs Buzzing About Smart Water Monitoring" (July 9, 2010).
[37] United States Environmental Protections Agency, "*WaterSense: Products*" (http://www.epa.gov/WaterSense)
[38] Department of Energy, Energy Efficiency & Renewable Energy, "*Water Efficiency: Best Management Practice: Alternate Water*" (http://www1.eere.energy.gov/femp/program/waterefficiency_bmp14.html#gwrs)

Industry leadership includes major indoor plumbing and fixture companies Brasscraft Manufacturing, Kohler, Price-Pfister, Zurn, and Moen. Most companies engaged in water recycling or gray water systems are fairly small.

Arizona's Current Position and Opportunities

In Arizona, many of the jobs involved in water efficiency and management are, centered on municipal water and wastewater treatment operations. While this is not a largely private sector activity, it does provide an important service for industry in Arizona, along with serving the residential sector.

Arizona is a national leader in research activities around water management and protection. Major grants from the National Science Foundation and U.S. Department of Agriculture to universities in Arizona focus on methods for integrated water and wastewater management, sustainable infrastructures for water supply, watershed management and restoration and development of arid and semi-arid lands.

Arizona is also a national leader in its regulatory approaches to gray water and the broader focus on the deployment and development of water reuse systems.

VII. CONCLUSIONS

Arizona has a considerable base of industry activity directly involved in producing green goods and services, or what the BLS has termed green economic output-related activities. Altogether, 1,711 establishments were identified by Battelle to be involved in the production of green goods and services, employing over 31,000 workers based on the most recent figures from the Dun & Bradstreet company database.

The largest segment of industries producing green goods and services in Arizona is found in pollution reduction and clean-up, which is closely associated with the longer standing traditional environmental industries that were borne from earlier environmental laws and regulations. Still, there is a growing presence of industry activity involved in non-traditional environmental sectors in Arizona, with 416 establishments involved in renewable energy, energy and resource efficiency, greenhouse gas reduction and education and compliance. The leading non-environmental green industry segments found in Arizona include solar PV and thermal energy, energy efficient building products and materials, and energy auditing.

From an economic development perspective, careful attention is needed to advance these industries involved in producing green goods and services. Many of the standard business climate issues confronting technology-related industry development in Arizona also affect the existing and emerging green economy companies – including the lack of investment capital, restrictive tax policies, and lack of educated workers. For example, PetroAlgae moved to Florida because they couldn't find any start-up capital in Arizona – they now have 150 employees in Florida.

In workforce development, there has been little ability to consider the breadth of workforce needs of firms involved in producing green products and services in Arizona because these firms are more typically grouped into broader standard industry classifications that go beyond green industries. This study suggests that a more focused effort of outreach to firms involved in producing green products and services is called for to identify specific areas of workforce shortages and the types of skill requirements needed.

Currently, Arizona's workforce system is giving a great deal of attention to the training requirements of weatherization firms that install energy efficient products. That sector employs about 2,200 workers in 116 firms. Another occupation of particular interest is solar PV energy installers – either first time training or upgrade training to broaden skill base into green areas (e.g., solar PV install skills for existing electricians). Currently, this sector accounts for about 95 firms, employing just fewer than 1,000 workers.

Still, the lessons being learned from these training programs are vital. For solar PV energy installers, workers – often already in the contracting business – need a more comprehensive approach to understanding the requirements of green technology development and deployment needed to advance a properly trained workforce. Solar PV install training and skill development and training efforts must include curriculum to help workers understand and correctly deal with performance parameters (e.g., tilt or shade issues for solar PV) and utility requirements. Similarly, future training in the "green building" space – whether to retrofit existing buildings or build new

ones – will need to incorporate knowledge of the "higher efficiency" building codes and certification requirements (across energy use, water use, and material use) coming out of ICC, USGBC, NAHB, and others.

The challenge is that many of these firms operate in traditional markets, as well as emerging green goods and services. For instance, many contractors who install energy efficient windows also do other work as well. So, training will need to focus not only on the workers but also on the business owners to help them understand the market opportunities and the need to invest in their workers to ensure that they can compete for rapidly growing markets in areas related to renewable energy production and deployment or energy efficient construction or equipment production.

Likewise, many service firms – professional architects, energy engineering consultants, or similar enterprises – will also need to invest in their workforce talent to compete for business opportunities that will increasingly demand an alternative energy or require greater efficiency in energy usage. Only by a focused outreach to firms involved in producing green goods and services can the interest in the opportunities be assessed and the general workforce needs and more specific skill requirements be fully understood.

APPENDIX A: EXAMPLES OF GREEN ECONOMY STUDIES AND BRIEF OVERVIEW OF DEFINITION OF GREEN ECONOMY USED

Study Name – Author	Green Definition

The CleanEnergy Economy – Pew w/ Collaborative Economics (6/09)	Main green sectors:
	• Clean Energy
	  o Energy Generation
	  o Energy Transmission
	  o Energy Storage
	• Energy Efficiency
	• Environmentally Friendly Production
	  o Transportation
	  o Manufacturing/Industrial
	  o Construction
	  o Agriculture
	  o Energy Production
	  o Materials
	• Conservation and Pollution Mitigation
	  o Air and Environment
	  o Recycling and Waste
	  o Water and Wastewater
	• Training and Support
	  o Business Services
	  o Finance/Investment
	  o Research and Advocacy
	• Did not include Nuclear or Clean Coal

Colorado Cleantech Cluster Analysis CORE and Evenson & Associates, December 2009	Main Green Sectors: • Agriculture • Air & Environment • Energy Efficiency • Energy Generation • Energy Infrastructure • Energy Storage • Manufacturing and Industrial • Materials • Transportation • Recycling and Waste Treatment • Water and Wastewater
Clean Tech Cluster Analysis Update for the Puget Sound Region Puget Sound Regional Council and Workforce Development Council of Seattle-King County, (11/09)	Main Green Sectors: • Clean Energy • Green Building • Smart Grid • Transportation Vehicles and Alternative Fuels • Advanced Materials and Environmental Products • Environmental Remediation and Pollution Prevention

Study Name – Author	Green Definition
Cleantech Cluster Profile 2008 – Portland Development Commission (5/09)	Focused on four main areas: • Alternative energy – did not include nuclear or clean coal • Environmental consulting & remediation • Green buildings • Energy efficiency.
Clean Power/Green Jobs – Union of Concerned Scientists (3/09)	• National forecast of jobs & economic development created by adopting a 25% RPS by 2025
CT Renewable Energy/Energy Efficiency Economy Baseline Study – CT Clean Energy Fund w/Navigant Consulting (3/09)	Primary energy focus: • Renewable energy • Energy efficiency • Did not include nuclear or clean-coal
Green Jobs in Minnesota: Market Analysis – MN Green Jobs Task Force w/ GSP Consulting (2/09)	• Broad green jobs focus, including four areas: renewable energy; green products (buildings, consumer, industrial, transportation); green services; and environmental conservation • Did not include nuclear or clean-coal.
Job Opportunities for the Green Economy – Political Economy Research Institute, UMass-Amherst (6/08)	• Focused on Efficiency Strategies (building retrofitting, mass transit, energy-efficient automobiles) and renewable energy (wind power, solar power, cellulosic biofuels) • Did not include nuclear or clean-coal.
Green Jobs in U.S. Metro Areas – U.S. Conference of Mayors w/Global Insight (10/08)	• Energy focus including efficiency • Did not include clean-coal.

APPENDIX B: BATTELLE SEGMENTS FOR GREEN PRODUCT/SERVICE CATEGORIES

BLS Defined Category	Detailed Segments
Renewable Energy	• Biofuels/Biomass • Wind Energy • Solar PV Energy • Solar Thermal Energy • Geothermal Energy • Hydropower Energy • Ocean/Wave Power Energy • Waste-to-Energy • Other
Energy Efficient Equipment, Appliance, Buildings, & Vehicles	• Architecture & Building Design • Battery & Energy Storage Technologies • Electric/Hybrid Drive Technologies & Vehicles • Energy Consulting & Auditing • Energy Efficient Appliances • Energy Efficient Building Products & Materials • Energy Efficient HVAC • Energy Efficient Lighting • Fuel Cells • Other Energy Efficient Products • Water Efficient Products • Smart Grid Systems/Smart Metering
Reducing or Removing Pollution, Greenhouse Gas Reduction and Recycling or Reusing Waste Materials or Wastewater	• Air & Water Purification • Air/Water/Sewage/Solid Waste Management & Treatment • Environmental Research & Consulting Services • Green Building Products & Construction Materials, NEC • Green Chemicals • Other Green Products • Pollution Prevention • Remediation Technologies & Services • Clean Coal • Nuclear Energy • Public Mass Transit • Recycled-Content Products • Recycling • Other
Organic Agriculture, Sustainable Forestry and Soil, Water and Wildlife Conservation	• Organic Farms/Organic Food Production • Conservation
Education & Compliance	• Compliance • Training • Advocacy

APPENDIX C: LISTINGS THAT BATTELLE EXAMINED TO IDENTIFY ARIZONA GREEN ESTABLISHMENTS

Specialized Listings Examined
• Company Lists from Plunkett's Alternative Energy, CorpTech, and Building Green (Green Spec) • "Clean" Venture Capital Index(s) • Venture Capital Information Related to Renewable Energy and Environmental Technologies/Services • VC Records - Other Environmental • Private and Public "Clean Economy" and "Mass Transit" (including Amtrak/Nat'l Passenger Rail Corp.) lists using D&B 8-digit SICs • Hybrid/Electric Automotive and Heavy Vehicle Manufacturers and Suppliers • Recently Received Patents Related to Renewable Energy and Environmental Technologies/Services • Energy Information Agency: Listings of U.S. Nuclear and Hydroelectric Generation Facilities • Registered Ethanol/Biodiesel Production Locations • Various Market Studies from BCC Research, Frost & Sullivan, Freedonia • Environmental Business Journal/Climate Change Business Journal
Certifications Examined
• DOE/EPA Energy Star - Installers/Services • DOE/EPA Energy Star - Products/Manufacturers • EPA Smart Way • EPA WaterSense • EPA Design for the Environment (DfE) • EPA Environmentally Preferable Purchasing (EPP) • EPA Comprehensive Procurement Guidelines (CPG) • USDA BioPreferred • USDA National Organic Farms & Food Certification Program • Underwriters Laboratory (UL) Sustainable/Environmental/Energy Efficiency Product Certifications & Verifications • Sustainable Forestry Initiative (SFI) Certification • Forest Stewardship Council Recycled Material Certification • Composite Panel Association Environmentally Preferable Products (EPP) • Carpet & Rug Institute Green Label/Green Label Plus Certification • National Association of Home Builders "NAHBGreen" and "Green Approved" Certifications • Level: Business and Institutional Furniture Manufacturers Association (BIFMA) Certification • California Recycled Content (incl. firms outside of California) • Cool Roof Rating Council Certification • Electronic Product Environmental Assessment Tool (EPEAT) Green Electronics Council Certification

Certifications Examined (continued)
• Green Seal (Third Party) Certification • GoodGuide (Third Party) Certification • SCS (Third Party) FloorScore Certification • GREENGUARD (Third Party) Environmental Institute (Third Party) Certification • SCS (Third Party) Indoor Advantage & Indoor Advantage Gold Certifications • MBDC (Third Party) Cradle to Cradle Certification • MTS (Third Party) SMaRT Certification • Solar Rating and Certification Corp. (Third Party) Certification • Sustainable Attributes Verification and Evaluation (SAVE) ICC Evaluation Service (Third Party) Certifications
Associations Examined
• American Solar Energy Society (ASES) • American Wind Energy Association (AWEA) • BioEnergy Producers Association • Biomass Thermal Energy Council (BTEC) • Geothermal Energy Association (GEA) • Geothermal Resources Council (GRC) • Gridwise Alliance • Growth Energy • National Association of Energy Service Companies (NAESCO) • National Hydrogen Association (NHA) • National Hydropower Association (NHA) • Renewable Fuels Association (RFA) • Solar Electric Power Association (SEPA) • Solar Energy Industries Association (SEIA) • United States Clean Heat and Power Association (USCHPA) • United States Fuel Cell Council (USFCC) • USA Biomass Power Producers Alliance (US BPA) • United States Green Building Council (USGBC)