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Defining, Measuring and Predicting Green Jobs

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Executive Summary

The purpose of this paper is to assess the "state of science" in defining, measuring and predicting green jobs. Estimating economic impact, including creation of jobs, of any major investment scheme is difficult as multiplier effects can change over time and there are often unintended consequences. The longer the time horizon it is, the less dependable do input-output coefficients become for predicting future jobs. With green jobs, there are further complications such as their definition and assumed labor intensities. Many of these industries are relatively new; some technologies are not even deployed in commercial scale. As such, the estimates of jobs per $ investment or per unit of energy output depend on small data sets, which probably renders them less reliable. Government support in the form of subsidies, tax breaks, direct investment grants, domestic content requirements and the like complicate the analysis further as these policies distort comparative cost advantages and often lead to adoption of more expensive technologies that impact the rest of the economy; can be transitory; can be redirected to different technologies; and can change over time. All of these uncertainties add to the inherent lack of precision in any modeling exercise and necessitate additional scenario and sensitivity analyses to cover all reasonable paths of development.

Overall, we conclude that adding "net jobs" cannot be defended as another benefit of investing in green energy (alternative energy technologies, energy efficiency and conservation). Each option offers benefits such as lower emissions and a more diversified portfolio, albeit at different levels. Models in studies reviewed analyze alternative scenarios and show net job gains but these are based on assumptions that are very aggressive (e.g., relative to official forecasts) and unrealistic (e.g., relative to the current state of technology, existing set of energy and environmental policies, availability of factors of production including financing – capital, shortage of infrastructure, uncertainty about consumer adoption and so on).

Common Issues

Despite different approaches in a range of studies reviewed, some common issues and inconsistencies are identified.

1) Perhaps most importantly, the different definitions of "green" jobs used by different studies demonstrate clearly the fundamental problem of comparing various studies' results. This problem led the Bureau of Labor Statistics to solicit comments of defining green jobs in early March 2010.[1]

    a) Jobs created are not always separated between construction jobs, which are temporary, and operation jobs, which are long-term.

    b) Some studies assume that green jobs will be higher paying than conventional energy industry jobs or average wage; but in the absence of more granular look at types of jobs and skill levels, this assertion is hard to justify. For example, there is no a priori

1 Federal Register, Vol. 75, No. 50, Tuesday, March 16, 2010, pp 12571-3.

reason to expect a generic construction job at a wind farm site will pay more than a similar position at another power plant site.

c) Jobs may not be "new" in that already employed people will be doing "green" work. Given the challenge of defining these jobs, counting an existing job as "new" doubles the chance of a miscount. A related complication is that some people may be doing green work while continuing to work in conventional fuel industries as well; there is no acknowledgement of "part-time" green jobs in any of the studies reviewed.

2) Often, there is no analysis of job losses.

a) Increased cost of energy to businesses and households will reduce consumption on other goods and services given the same budget, which will translate into job losses in these other sectors. As some of the studies recognize, green technologies generate more expensive electricity or yield more expensive fuels with current technology. With economies of scale and more R&D, many of these technologies will have lower costs in the future but there is no agreement in what time frame and by how much.

b) Loss of traditional industry jobs. Green technologies will replace demand for conventional fuels and technologies, which will undoubtedly lead to lay-offs in these industries.

3) Some macroeconomic benefits such as increased productivity, higher disposable income, and lower cost of doing business are not backed up by any evidence and are inconsistent with the realities of green technologies and energy markets. For example, higher labor intensity and higher energy costs (as acknowledged by at least some of the studies) that result from rapid expansion of green technologies will increase cost of doing business and reduce disposable income ceteris paribus.

4) The studies depend on very aggressive growth assumptions for renewable power, far above official government forecasts. For example, Global Insight (2008) assumes renewable generation excluding conventional hydro (currently about three percent of the sector) to increase its share to 27 percent by 2028. According to *Annual Energy Outlook 2008* by the Energy Information Administration (EIA), renewable energy generation (including conventional hydro) will grow at an average rate of two percent per year and reach 12 percent of the total generation capacity by 2030 from nine percent in 2008.

5) Most studies do not address how much it would cost both in terms of capital investment and, more importantly, end-user prices of electricity and transportation fuels. There are lump-sum stimulus assumptions in some studies but they are not directly related to investment in MWs or Btus. Investment requirements and time frame assumptions vary widely between the studies. Resulting job creation estimates also differ significantly (see table below for a sample of studies).

Investment scenarios of different studies				
Studies	***New renewables***	***Investment***	***Jobs created***	***Time period***
Pollin et al (2008)		$100 billion	2 million	2 years
Global Insight (2008)*	~750 GW	>$1.5 trillion	1.2 million	30 years
Asmus (2008)**	20 percent RPS by 2017		200,000 (CA only)	15 years
Asmus (2008) (Apollo Alliance)**		$500 billion	5 million	10 years
Asmus (2008) (WWF)**			1.3 million	2001-2020

* Our estimate based on the Global Insight (2008) scenario of increasing power generation from renewables (excluding conventional hydro) from 3 percent in 2008 to 40 percent by 2038. Note that we are not including the Global Insight (2008) scenarios for transportation fuels and efficiency investments.

** Asmus (2008) focuses on job creation in California. The range of estimates for green job creation in California is reported as 16,000 to 430,000 by 2020 (p. 9). In this table, we provided, when available, national estimates from the same studies to compare with estimates from other studies.

6) An implicit, and sometimes explicit, assumption in many studies is that there is an unlimited supply of labor that will be ready to fill green job openings. Although this may be true for unskilled construction jobs, which are temporary, some skilled jobs may not be that easy to fill. The existence of many training programs for wind, solar and biofuels industries indicate that some additional skill development is necessary. Also, BLS statistics show that unemployment for managerial, business and professional positions have been about five percent despite the economic slowdown; it may be more difficult to attract experienced employees for such positions.

7) Many studies count on protectionist policies (tariffs on imports, local content requirements, etc.) to support the cultivation of domestic industries. But, the industry is already globally competitive; Chinese, Indian, Korean companies compete with established companies from Europe and the U.S. in wind, solar and other technologies and offer cost advantages. Protectionist policies will lead to higher cost products, hence amplifying the higher cost impact of green technologies on consumers and businesses.

8) Although claiming reduced dependence on oil imports and/or lower oil prices is attractive to supporters of green technologies, it is important to realize that this linkage is very weak. Very little oil is used for power generation in the U.S.; hence the increased use of wind, solar and other renewables will have a negligible effect if any. Most oil is used for transportation; biofuels or electric cars offer some alternatives, but their penetration has been quite limited. Finally, oil market is global. Although the U.S. has been the largest consumer for decades, led by China many other countries are expanding their consumption and supply is having difficulty to catch up due to environmental

restrictions on drilling in the West and resource-rich countries limiting access to their resources. In this environment, incremental reductions in US oil consumption will not reduce the price of oil. Also, financialization of oil has led to pricing in futures markets that can be detached from physical demand and supply fundamentals at least for some period of time.

9) There is no consideration of challenges such as lack of transmission (cost and ability to site), technical limitations of integrating large amounts of intermittent sources such as wind into the grid (lack of storage, asynchronous nature of wind generation and daily loads, frequency mismatch, etc.), and NIMBY attitude for even renewable facilities.

10) Job creation statistics and the opportunity cost of green investments in terms of job creation deserve special attention. Comparison of economic impacts of similar investment in other segments of the economy (energy or non-energy) is often lacking. Some studies offer investment in green jobs as a solution to economic slowdown or recession. If this Keynesian approach were to be followed, there are other sectors of the economy that could create more jobs for the same dollar of investment.[2]

The summary of investment scenarios in the table above captures the fundamental issues. There is a high level of uncertainty surrounding the jobs estimates of these studies, partly because they use different definitions of a green job. But the estimates differ significantly also because the studies use different models to estimate job creation and different investment scenarios. Also, there is little to no effort to balance the potential positive impacts with potential negative impacts of job losses and higher energy costs. In a sense, many studies are cost-benefit analyses without adequate cost considerations.

2 Huntington (2009) provides a useful comparison on this issue and is discussed in further detail in this report.

Background

Energy efficiency, conservation and alternative energy technologies are important components of addressing energy security and environmental challenges. Their role has been expanding and, without doubt, they will play an increasingly larger role in future energy policies. In addition to relatively established technologies such as wind, newer technologies such as biofuels using different agricultural and waste feedstock, advances in solar PV and thermal, and electricity storage are in various stages of research and development, and some even are being commercialized. Differing technologies offer a varying array of benefits and trade-offs including cost structures, reliability of supply, need for back-up generation and emissions profiles. These are appropriate criteria to consider when evaluating energy policy options.

Often, however, creating jobs is also offered as a benefit associated with investment in these energy technologies. Some take it further and offer green jobs as a way out of recession (especially after the economic collapse in 2008) and a path into a sustainable growth economy.[3] Such studies claim that investment in these technologies would create more jobs than investment in other energy industries, which would be true only if they require more labor per dollar than conventional technologies they replace. This argument is economically problematic as it implies lower productive efficiency and hence higher labor cost of production, with its negative impact on consumer budget and competitiveness of businesses in the global market.[4]

Some alternative technologies may in part be more expensive than established technologies due to lack of economies of scale; and their costs may decline with expansion. Also, mitigation of some of this cost disadvantage via incentive programs may be justified based on environmental and diversification benefits green technologies may provide; but if they are also more labor-intensive and will likely remain so, their cost disadvantage may remain permanent. The enduring higher cost structure seems to be the case at least for the biofuels industry that depends on the agricultural, animal farming and forestry sectors that tend to be more labor intensive. Even the wind generation costs that have declined consistently over the years have been experiencing inflation in recent years (Wiser and Bolinger, 2010).

Promoting the job creation aspect of green technologies may in fact undermine their expansion. About 30 jurisdictions in the U.S. have renewable mandates or targets; many have implemented a renewables portfolio standards (RPS) program, with associated trading of renewable energy certificates, or credits (RECs). In many of these states, creating local jobs/content is a goal that shapes the RPS program. It is often necessary to introduce this goal to garner sufficient support in state legislatures to pass laws that establish renewables mandates and RPS programs. Naturally, states favor the resources with which they are endowed or technologies for which the state might have some competitive advantage in terms of manufacturing or supply chain since they would create the most jobs. To further protect

3 For example, see Barbier (2009), Asmus (2008) and Pollin et al (2008).

4 Many of the green technologies do not have fuel costs but current cost estimates for renewable electricity or biofuels are mostly higher than conventional electricity and liquid fuels despite the cost of fossil fuels. Higher labor cost is a significant contributor to the cost structure of green technologies.

development of local business, RECs from other states are not allowed in some states to meet RPS obligations. If one state has more potential for development (e.g., high quality wind, solar or geothermal resources) and its own RPS mandate is already met, their incentives to build new generation will be curtailed since the excess credits would not be valid in other states; producing more within the state would simply collapse the REC price in the state. It is also often the case that states with RPS programs that do not allow out-of-state credits end up with more expensive technologies and hence higher electricity prices. This focus on local jobs and economic development is a handicap for the efforts to create a regional, or even a national, market for RPS programs that could facilitate more investment in areas where the most cost-effective resources could be harnessed.5 Interestingly, many studies promote similar "local content" policies to support their argument in favor of green jobs having a net positive effect on the domestic economy. This "beggar thy neighbor" policy approach may be good politics but is not likely to yield globally optimal outcomes.

Following is a more detailed discussion of some of the major challenges facing efforts to estimate green jobs based on certain policy scenarios.

Challenges

There are many challenges that face studies estimating green jobs over extended periods of time. Some of these issues are common across similar studies estimating job creation from investment in any sector of the economy and include static nature of input-output models, uncertainties associated with policies, intricacies of consumer behavior (hence, difficulty of predicting how consumers may react to certain policies)[6] and external shocks, which are by definition unpredictable.

However, studies focusing on green jobs face additional challenges, first of which is defining what constitutes a green job. Many green technologies are relatively new, representing a small share of the market and lacking sufficient economies of scale to have achieved their long-term cost structure with the possible exception of onshore wind. Although it is reasonable to expect that at least some of these technologies will continue to evolve and that their costs will be reduced, it is difficult to compare all of these technologies and identify front-runners. Unless these paths of technology evolution are well understood, how many people will be employed by which technology, what skills these jobs will need, what kind of wages they will pay, what kind of market entry support these technologies will need and many more questions will remain difficult to answer. And without these answers, the accuracy of cost, price, and wage assumptions made during modeling exercises will remain questionable. The following is an effort to group some of these issues under recognizable categories, using examples from some studies with different approaches.

5 Gülen et al (2009a) and Gülen et al (2009b) provide details on various RPS programs in the U.S.

6 Consumer behavior is an interesting area of research and one that attracts a lot of attention from promoters of energy efficiency, smart grid and similar technologies because consumers do not always behave as expected when it comes to buying green equipment or changing their consumption habits and there are gaps between what they say in polls and what they do (Ehrhardt-Martinez, 2008). A recent report by the American Council for an Energy-Efficient Economy (Friedrich et al., 2010) highlights the challenges and provides case studies on how to influence consumer behavior.

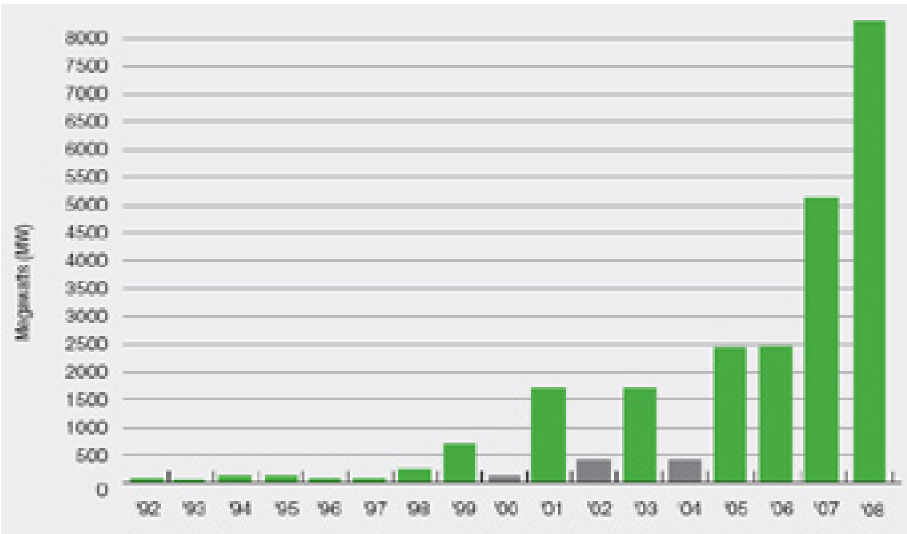
Defining green jobs

Almost every single study defines the realm of green jobs differently from others. The Bureau of Labor Statistics (BLS) in the U.S. recognizes this fact in stating that "There is no widely accepted standard definition of "green jobs." While this topic is of interest across government, academia, and the business community, various studies define the term differently."[7] In its effort to standardize the definition, BLS classifies "jobs involved in economic activities that help protect or restore the environment or conserve natural resources" as green jobs, which includes recycling, pollution reduction, organic farming, and similar non-energy activities.[8] As such, if one was focusing on the impact of renewable energy technologies, counting all of these categories in their analysis would inflate the results. BLS industry codes allow researchers to select the industries that are relevant for the particular research question but this does not seem to be the approach taken by many studies.

In most studies, jobs created are not always separated between construction jobs, which are temporary, and operation jobs, which are long-term. Counting construction jobs going forward introduces an upward bias based on an implicit assumption that there will be constant or even increasing level of new construction. The history of wind investment in the U.S. shows that this is a risky assumption; as federal production tax credit was allowed to expire at different times, investment in wind fell significantly in the following year (Figure 1). Alvarez et al (2009) identifies the same problem for the Spanish case (p. 21).

Also, jobs may not be "new" in that already employed people will be doing "green" work. The biofuels sector is a good example since it will use agricultural crops or byproducts as

Figure 1. Annual installed wind capacity and the impact of PTC
Source: data from American Wind Energy Association (AWEA) as reported by Union of Concerned Scientists. (http://www.ucsusa.org/clean_energy/solutions/big_picture_solutions/production-tax-credit-for.html)



7 In a comment request published in Federal Register, Vol. 75, No. 50, Tuesday, March 16, 2010, p. 12571.

8 This BLS definition is pretty consistent with the definition provided in Worldwatch Institute (2008) report for the United Nations Environment Programme: "We define green jobs as work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution."

well as waste from animal farms. Classifying jobs in these sectors as “new” or “green” can be erroneous if it includes existing jobs. For example, if a farmer switches to, say, rapeseed from wheat to supply the biofuels industry, he cannot be considered as newly employed. His income may change but he would continue to farm regardless of the existence of the biofuels industry. The situation gets more complicated if the farmer does not switch crops but supplies agricultural waste to the biofuels industry; should he be considered a green worker or only part-time green worker? Either way, his is not a new job.

This challenge is acknowledged in Worldwatch Institute (2007) survey of multiple green job studies for the United Nations Environment Programme (UNEP), which also recognizes that some jobs will be “eliminated without direct replacement” and that “some employment will be substituted”. In terms of jobs accounting, transformed and substituted jobs cannot be counted as additional employment; and eliminated jobs should be subtracted. Most aggressive studies do not seem to be following these principles.

Perhaps most significant cause of optimistic estimates is that the definition of a green job is quite inclusive but not always clearly framed. For example, in Pollin & Wicks-Lim (June 2008),[9] it is stated that “Train operators who currently deliver furniture may one day deliver wind turbine component parts, meaning that their work will be contributing to a green economy that solves global warming and builds healthier communities.” It is not clear whether the train operator will be considered only a part-time green job if they continue to deliver furniture along with wind turbine components. Regardless, with such an open-ended definition, almost any job can be considered a green job since it is likely that some green work will be done at some point by most service providers. For example, an electrician who works on a refinery may also do work at a geothermal facility or a windmill; or a welder who works in construction of oil rigs can also work in the construction of renewable facilities such as offshore wind farms.

Global Insight (2008) counts nuclear industry jobs, agricultural jobs supplying corn to ethanol plants and government jobs in environmental administration as green jobs. As the authors acknowledge, many in the environmental community would not accept nuclear technology as green. Also, hydro and biomass are counted as green alternatives. But, there is opposition to hydro facilities, especially larger dams, due to their negative impact on the ecology around their reservoirs and flow paths. Collection and combustion of biomass is not free of emissions, and hence of opposition, either. The net balance of energy and emissions for corn-ethanol can be worse than conventional fuels in a life-cycle basis. For example, Delucchi (2006) using the Lifecycle Emissions Model (LEM) by the Institute of Transportation Studies at the University of California, Davis estimated a range from 30 percent reduction to 20 percent increase in greenhouse emissions.[10] Global Insight (2008) acknowledges this challenge in footnote on page 11: “…there is debate over whether corn-based ethanol and soy-based biodiesel should be considered Green Jobs due to high energy and water usage in the production of crops. We consider them as alternative fuels here because of their ability to reduce reliance on fossil

9 The definitions from Pollin & Wicks-Lim (June 2008) are used in Pollin et al (September 2008).

10 Also see previous publications by Delucchi and his colleagues at http://www.its.ucdavis.edu/people/faculty/delucchi/.

fuels." This bundling of energy security concerns with greening of the economy goals is a common pitfall, which undermines readers' ability to distinguish between "alternative" jobs and "green" jobs.

The largest category of green jobs in Global Insight (2008) is in the "engineering, legal, research & consulting" category (419,000 out of a total of 751,000, or 56 percent). Given that there are also categories for renewable generation, manufacturing, construction & installation, it is likely that the majority of the jobs in the largest category are not directly associated with the generation of a single kWh of "green" power or a single Btu of "green" fuel. Also, in all likelihood, engineering, legal, research and consulting firms that are engaged in the green industry allocate a certain portion of their human resources to this sector, especially in larger firms. It is not stated in the study whether only a portion of their employees or the full labor force of a company are counted in these calculations.

The studies surveyed for Asmus (2008) yields a wide range of job estimates (between 16,000 and 430,000 by 2020). There is no detailed explanation provided for different scenarios and assumptions that lead to such a wide range; but a fundamental factor that contributes to such discrepancies is the definition of green jobs. Another factor is the assumptions about multiplier effects of direct green jobs on the rest of the economy. A wide-ranging definition of green jobs will lead to larger impacts in most models than more specific definitions; this impact can be further enhanced if multiplier effects are also generous leading to many indirect jobs. Multipliers for green industry, in turn, depend on excess capacity in the economy (see the discussion on availability of labor below) and can be difficult to estimate for a relatively new supply chain in the US economy.

Job losses

When policies such as cap-and-trade, higher RPS mandates, higher energy efficiency standards and others are implemented, it is generally accepted that the cost of energy will likely increase at least during initial years and especially if mandates are aggressive. We know this because with current technology, subsidies and tax breaks are necessary to induce producers to build wind and solar facilities, and consumers to buy energy efficient appliances and conserve energy. Carbon taxes could level the playing field by increasing the cost of conventional fuels but will increase the cost of energy. But note that although a carbon tax of $20-30 per metric ton may be sufficient to render wind competitive with conventional fuels, other technologies require a much higher carbon tax.

Many studies investigated the impact of incentive policies on economic output, employment and/or disposable income. For example, Charles River Associates (2009) and Beach et al (2009) evaluated the American Clean Energy and Security Act of 2009 (ACESA, HR 2454) and concluded that national employment, GDP and disposable income would decline if the bill were implemented. EPA (2009) also predicts GDP losses, albeit less than the other studies; the lower GDP loss estimates may be due to the assumption that other nations will adopt similar GHG regulation policies. Chamberlain (2009) estimates the impact of a cap-and-trade policy that calls for 15 percent reduction of GHGs from 2006 levels and concludes that

“Depending on how the system is structured, cap and trade could reduce U.S. employment by 965,000 jobs, household earnings by $37.8 billion, and economic output by $136 billion per year or roughly $1,145 per household.”

There are state level studies also showing similar results. For example, Texas Comptroller of Public Accounts’ evaluation of ACESA concluded that “…Texas could lose 170,000 to 425,000 jobs by 2030 as a result of those increased energy prices.”[11] Hillebrand et al (2006), in their evaluation of Germany’s renewable policy, concluded that expansionary impact of new investment in renewables will dominate in early years but higher cost of power production will have a contraction impact, which will dominate in the longer term, resulting in “slightly negative employment balance in 2010.”

Yet, most studies on green jobs with the exception of Ragwitz et al (2009), do not even mention potential of significant job losses.

Macroeconomic impacts

There are often generalizations about macroeconomic benefits that are not backed up by any evidence (or details of the modeling exercise) nor qualified as “possible” or “likely”. Most of the time, these assumptions are inconsistent with the realities of green technologies and energy markets. For example, from page 2 of Global Insight (2008): “The economic advantages of the Green Economy include the macroeconomic benefits of investment in new technologies, greater productivity, improvements in the US balance of trade, and increased real disposable income across the nation. They also include the microeconomic benefits of lower costs of doing business and reduced household energy expenditures. These advantages are manifested in job growth, income growth, and of course, a cleaner environment.”

There is a lack of evidence for making the claim for greater productivity, especially given the likely outcome that “green” energy sectors would likely be more labor intensive than conventional energy sectors. Ragwitz et al (2009) among others indicate that some of the green technologies are more labor intensive, especially biomass, which depends on agriculture. Also, when compared to conventional technologies on unit of energy output, due to intermittency and low capacity factors, wind and solar are likely to be more labor intensive (hence less productive). In fact, as discussed before, many studies actually count on the fact that per dollar of investment, green technologies are more labor intensive to support the greater job creation argument.

Furthermore, an increase in real disposable income would require lower cost energy or higher wages, or both. It is difficult to decipher how energy costs that are likely to rise (Ragwitz et al (2009) acknowledges this rise) and wages that may or may not be higher economy-wide lead to increased real disposable income or lower energy expenditures. In contrast, Roland-Holst (2008) promotes a scenario where there is cap-and-trade that increases the cost of conventional fuels relative to alternatives, and where energy efficiency improvements

11 Please see http://www.window.state.tx.us/finances/captrade/perspective.html. CEE-BEG collaborated with CPA on this analysis.

continue into the future at historical or higher rates thanks to innovation. The focus of the report is energy efficiency policies in California and their impact on job creation. These assumptions are not based on standard practice as recognized by the author on page 34: "Since there is no agreement in economic theory or empirical work about how to model innovation processes, we can still elucidate this question, however, by posing a hypothetical scenario that provides a metric for the costs and benefits with enhanced efficiency. In the present analysis, we factor in the prospect of innovation to reduce energy intensity by projecting a rate of energy efficiency gains that better reflect historical achievements, as well as the impact of significantly more aggressive policies aimed to reduce energy use." Finally, Roland-Holst (2008) uses a computable general equilibrium model (Berkeley Energy and Resources, or BEAR), which by all accounts appear to be appropriate to analyze the impact of various macroeconomic policies on the Californian economy. But as other CGE models, it is not equipped to capture specifics of individual technologies (in this case, we would be interested in energy efficiency technologies and their potential for innovation) and hence the need for the projection of a rate of historical energy efficiency.

For cost of doing business and household energy expenditures to decline, higher efficiency or lower energy costs or both would be required as a result of the proposed policy. Again, higher labor intensity and higher energy costs that are more likely outcomes of rapid expansion of green technologies will increase not decrease cost of doing business.

Demand growth

In many studies, job creation estimates are based on green technology growth scenarios that are significantly more aggressive than commonly referenced forecasts by the EIA or International Energy Agency (IEA) among others. For example, Global Insight (2008) depends on some very aggressive growth assumptions for renewable power, far above official government forecasts. For example, according to the *Annual Energy Outlook 2008* by the Energy Information Administration (EIA), renewable energy generation (including conventional hydro) will grow at an average rate of two percent per year and reach 12 percent of the total generation capacity by 2030 from nine percent in 2008.[12] But the GI scenario is for renewable generation excluding conventional hydro (currently about three percent of the sector) to increase its share to 27 percent by 2028 (page 12).

Asmus (2008) targets 33 percent share for renewables in California by 2020. In 2010, excluding conventional large hydro, 12-13 percent of electricity in California is generated by renewables. Including large hydro, California gets more than 24 percent of its electricity from renewable sources. Asmus (2008) appears to include large hydro in the 33 percent goal (Figure 1 on page 5) but as mentioned before large hydro is controversial. The study does not advocate construction of large hydro but rather focuses on wind, solar, geothermal and other green technologies to meet the target. In fact, the author criticizes California Public Utilities Commission for its efforts to protect consumers against higher energy prices by

12 In AEO 2010, EIA estimates the share of renewables and biofuels in primary energy consumption will reach 13 percent by 2030, slightly more optimistic than AEO 2008 but still less than half of the Global Insight (2008) scenario of 27 percent despite including hydroelectricity.

capping the price of renewables generation relative to natural gas prices. As such, the study admits the higher cost of green technologies and that consumers, either through their energy or tax bills, will have to pay higher prices to achieve the 33 percent goal. However, there is no counterbalancing discussion of the negative impacts of these higher energy costs on the household consumption and business competitiveness.

Pollin et al (2008) states in page 2 that "Employment in construction fell to 7.2 million in July 2008, down from 8 million in July 2006. A green economic recovery program would replace, at least, those 800,000 lost construction jobs over the next two years, and could result in renewed investment in the housing sector that is at the root of the current economic slump." There is already an oversupply of housing; housing starts fell from a high of 2,068,100 in 2005 to 553,900 in 2009.[13] Occupancy rates collapsed in 2008-09 and are just starting to recover in second quarter of 2010.[14] It is not likely that there will be large scale investment in new housing for the next few years.[15] Investment in energy efficiency improvements (for example, adding insulation, switching to more efficient appliances and light bulbs) would create jobs but would not be enough to replace lost construction jobs. A recent study by CAP itself, Hendricks et al (2010) concluded that "upgrading just 40 percent of the residential and commercial building stock in the United States would create 625,000 sustained full-time jobs over a decade." ACEEE estimated that about 250,000 jobs would be created by the energy efficiency provisions in ACESA (H.R. 2454) by 2020, with a total of 650,000 jobs generated by 2030.[16] Estimates for new jobs from both studies are below 800,000 lost construction jobs and are realized over 10 to 20-year time frames.[17]

Bezdek (2007) for the American Solar Energy Society (ASES) is another study that is built on assumptions that are much more aggressive than benchmark forecasts. The study estimates that, in 2006, 452,000 jobs (direct and indirect) were created in renewable energy and more than eight million jobs were created in the energy efficiency industry. The study's 2030 base case forecasts are 1.3 million jobs in the renewable energy and 15 million jobs in the energy efficiency industry. Moderate (3.1 million and 17.8 million) and advanced scenarios (7.9 million and 32.2 million) are much more aggressive.

Worldwide, renewable energy (including power generation and biofuels) met approximately 48.8 quadrillion Btus of demand in 2007 or 10% of total demand (*International Energy Outlook 2010* by the EIA). Under their IEO reference case, the EIA estimates 91.2 quadrillion Btus of primary energy as originating from renewable sources in 2030. The ratio of the two quantities is 1.87 (91.2/48.8) and can serve as a useful proxy for the upper bound of the ratio

13 Statistics from the web site of National Association of Home Builders: http://www.nahb.org/generic.aspx?sectionID=130&genericContentID=554.

14 See the news item and associated data at NAHB's web site: http://www.nahb.org/news_details.aspx?sectionID=238&newsID=11312.

15 David Crowe, NAHB's Chief Economist put it as follows: "Lenders have been unwilling to fund multifamily development, because the inventory of rental housing expanded from traditional multifamily communities to foreclosed and investor-owned single-family homes made available for rent as a means of creating a temporary cash flow until the homes can be sold." http://www.nahb.org/news_details.aspx?sectionID=238&newsID=11312.

16 http://climateprogress.org/2009/06/09/waxman-markey-energy-efficiency-savings-jobs/.

17 The number of lost construction jobs has increased to 2.1 million by the time Hendricks et al (2010) was published.

of jobs required for the 2007-2030 period if one assumes that the industry not only affects US energy consumption but world energy consumption. The ratio is an upper bound given that expected increases in productivity of the renewable energy workforce are not captured by the ratio and that worldwide labor intensity is probably much larger than in the U.S. If we apply the 1.87 multiplier to 452,000 jobs in 2006, we get 841,500 jobs in 2030, much less than the 1.3 million forecasted by Bezdek (2007) for the base case. Overall, the numbers reported in the study for the base case are not consistent with the energy outlooks for renewable energy. The other scenarios consider a much wider penetration of renewable energy sources and increased energy efficiency; and as such yield job estimates that are very much out of line when compared to standard outlooks.

Also worth noting is how large the absolute value of employment numbers are relative to total population and labor force. Under the advanced scenario, the total number of jobs associated with the RE&EE industry is estimated to be 40.1 million in 2030, which is equivalent to 11 percent of the total expected population of the United States in 2030 (363 million according to the 2000 census) and an even higher percentage of the non-farm payroll. In 2007, when unemployment was much lower than today, the non-farm payroll was about 138 million, or 46% of total population. Assuming the same ratio will hold true in 2030, non-farm payroll would be about 167 million. Under the advanced scenario of Bezdek (2007), 24 percent of all non-farm payroll employment would be in RE&EE industries. These high percentages suggest an inclusive definition of direct green jobs and large multipliers to obtain large indirect green jobs.

Worldwatch Institute (2008) study for the United Nations Environment Programme (UNEP) cites Bezdek (2007) several times but concludes that job estimates are overstated: "…They are based on the assumption that existing U.S. government standards and efficiency ratings are sufficiently indicative of (currently) achievable energy efficiency. At least in some respects, however, this is a somewhat questionable assumption, and it follows that the ASES findings overstate the extent of existing green jobs" (p. 9). Bezdek (2007) counts large hydro and biomass (including corn ethanol) industry employment as green jobs; UNEP report points out that large dams and corn ethanol are problematic from an environmental point of view and that their employment should not be counted towards green jobs.

Availability of investment dollars

Most studies acknowledge, mostly tacitly, the fact that private funding will not be sufficient to achieve large scale penetration they envision. This is because of the higher cost of most of these technologies and the need for new infrastructure. Therefore, they focus on public financing. For example, Pollin et al (2008), using the job categories identified in Pollin and Wicks-Lim (2008), analyze the effects of a $100 billion stimulus package ($50 billion in tax credits, $46 billion in direct government spending, and $4 billion in loan guarantees) over two years. The scenario envisions that this amount would be met by revenues generated from the auction of CO_2 emission permits under a cap-and-trade scheme, though up-front costs would be met by deficit spending. The study estimates that two million new jobs would be created with this stimulus.

The authors claim (page 15) that despite spending \$100 billion over two years, the creation of two million new jobs will help the government to "restore fiscal balance." But there are no calculations or evidence provided on how the fiscal balance will be restored, especially considering the fact that deficit spending is proposed to cover upfront program costs. The only explanation in the study is the revenues from auctioning CO_2 permits under a cap-and-trade system. The study provides a range of revenue estimates from \$75 to \$200 billion. But no references or underlying support for the estimates are provided; nor are the CO_2 price assumptions or time frames known. An estimate of \$750 billion over 10 years is provided from another CAP study but again no details about CO_2 price or time frame are provided.

Although the study claims that this revenue stream is not speculative, there is no cap-and-trade program in the U.S. and there will not be one in the foreseeable future. The most ambitious energy and climate bill in recent years was offered by Representatives Waxman and Markey in American Clean Energy and Security Act of 2009 (ACESA, HR 2454). The auction envisioned in this bill would not have generated the \$100 billion assumed in the CAP study. Entities covered by the Act contribute about 85 percent of GHG emissions in the U.S. (about 7 billion metric tons of CO_2-equivalent). The goal was to reduce covered emissions by three percent below 2005 levels in 2012, 17 percent below 2005 levels in 2020, 42 percent below 2005 levels in 2030, and 83 percent below 2005 levels in 2050. These targets translated into a cap of 4.5-5 billion metric tons for the initial years starting 2012, which would necessitate regulated entities to acquire 2-2.5 billion metric tons worth of permits. But, HR 2454 provided for only 15 percent of CO_2 emission permits to be auctioned, handing out the rest for free. The bill also allowed international offsets the companies could employ rather than buying permits in the U.S. Even if all 15 percent of 2.5 billion tons worth of permits had to be purchased domestically at \$30 a ton, that would generate \$11.5 billion in 2012. But, all of these revenues were allocated to reducing impact of higher energy prices in consumer bills; they would not be available for the type of programs proposed in the CAP study.

The ACESA bill died later in 2009 in the Senate. Currently, there is no prospect for a climate change bill in the U.S. Congress. Even if there was a cap-and-trade market, the experience in Europe over the last several years has shown that CO_2 prices can be very volatile and low, especially if the permits are freely and/or preferentially distributed. One reason for lower price of CO_2 permits is the global economic malaise that reduced demand, with accompanying reduction in emissions. The U.S. emissions have also declined in 2008 and 2009 due to economic slowdown. In general, higher cost of oil and energy has been causing significant improvements in energy efficiency and conservation, reducing energy intensity and emissions per unit of output.

Ladislaw and Goldberger (2010) provide a wider perspective on comparing green stimulus programs across several regions (the U.S., China, South Korea, and Europe). Often stimulus funds cannot be dispersed quickly, waiting for bureaucracy to catch up with the legislation. Sometimes, as in the case of the U.S. program, projects have to be "shovel-ready" and be able to raise private capital to be eligible for parts of the stimulus funding; this requirement eliminates many technologies. For example, in August 2010 it was reported that \$3.4 billion worth of smart grid projects were at risk of not getting funding from DOE since they may not finalize their contracts with DOE, suppliers and utilities and/or filings with regulators by the fiscal year deadline.[18] As of September 30, 2010 (deadline), out of $35 billion appropriated to DOE under the American Recovery and Reinvestment Act of 2009 (ARRA), about $33 billion have been awarded to various projects but only $8 billion have been spent.[19] Because of such bureaucratic constraints, counting on large government funding in a relatively short period of time to justify aggressive green deployment scenarios is difficult to defend.

On a related note, Pollin et al (2008) also call for "lower public transportation fares" (page 7) in addition to large new investment in mass transit to be paid by the $100 billion. But, it does not appear that fare reductions are covered by the $100 billion stimulus package. As a result, the mass transit companies would not be able to recover their investment and/or operating expenses from ridership and would have to go back to the government for more support. Also, if the ridership does not rise because people start telecommuting more or alternative fueled vehicles become more prevalent, or both, transit companies would need further support. Another issue is maintenance and expansion of the roads. Most roads, especially highways, are built and maintained based on revenues from taxes imposed on transportation fuels such as gasoline and diesel. Many roads in the U.S. have already been suffering from lack of maintenance. Significant reduction in traditional fuel use would necessitate a restructuring of taxes, including introduction of some new taxes, to compensate for the loss of revenues.

Since private financing of green technologies of the scale envisioned most green jobs studies is not likely to happen in the absence of large mandates, bigger tax incentives and other facilitating conditions, public financing is often seen as necessary and more direct way of achieving larger penetration of green technologies. However, the myriad of issues associated with public financing of projects, funding appropriation process, local versus federal budgets, and bureaucratic procedures are ignored in almost all of the studies. Admittedly, these "realities" in the ground are difficult to capture in modeling exercises but they can and do delay or prevent projects from taking place and deserve attention in any credible assessment of the scope and timeline of green investments.

Labor pool: availability and skills

An implicit assumption in many studies seems to be that there is an unlimited supply of skilled and unskilled labor that will be ready to fill green job openings. For example, Pollin et al (2008) states that "Of course, beyond construction, we are still left, as of July 2008, with 8 million additional unemployed workers in other sectors of the economy. There is thus little chance that we will face serious labor shortages through creating 2 million more jobs overall." (page 12). Another example is provided on page 13 of Global Insight (2008): "The technology of wind electricity is relatively new, but the manufacturing base for its production is very similar to past products. Every state in the country has firms and a labor force with

18 "DOE Stimulus Deadline Looms: $3.4 Billion in Limbo?" by Liz Enbysk, Smart Grid News, Managing Editor (http://www.smartgridnews.com/artman/publish/Stimulus_Awards_Projects_News/DOE-Stimulus-Deadline-Looms-3-4-Billion-in-Limbo-2851.html)

19 Data is available at http://www.energy.gov/recovery/data.htm.

experience making products similar to the blades, gearboxes, brakes, hubs, cooling fans, couplings, drives, cases, bearings, generators, towers and sensors that make up a wind tower. These jobs fall into the familiar durable manufacturing sectors of plastics and rubber, primary metals, fabricated metal products, machinery, computer and electronic products, and electrical equipment."

The construction sector may have additional labor to meet the new demand but, when it comes to skilled professions, supply may not be that elastic. An investigation of the unemployment statistics from the Bureau of Labor Statistics (BLS) show that unemployment rate in construction, materials moving, transportation and installation types of jobs has been 15-25 percent but unemployment in skilled jobs, especially managerial, business and professional positions have been about five percent.[20] These data do not necessarily disprove the statement made in Pollin et al (2008) but raises serious doubts about its soundness. More importantly, these data demonstrate the complexity of labor market in the U.S. and difficulty of making general statements about availability of labor for any particular job or sector. Finally, competition for skilled labor can always lead to wage wars between companies or sectors, complicating our ability to forecast labor movements further.

Also, eight million additional unemployed cannot be offered as the labor pool. The "full employment" (or, natural, or structural) rate of unemployment is often considered between 4-6 percent. Historical data from the BLS show that the unemployment rate has not fallen below 4 percent since the late 1960s, except for several months in 2000, when it was 3.9 percent. Some of the eight million who lost their jobs in late 2000s may have retired; for the next several years, unemployment may settle around 6-7 percent rather than the 4-5 percent range, in which case some of the eight million will never be able to go to work.

Pollin et al (2008) also claim that "It will also strengthen career ladders by providing pathways for workers to move up from lower-paying to higher-paying green jobs that can be created on a geographically equitable basis throughout all regions of the country." There is no indisputable evidence on green jobs paying higher salaries than comparable jobs in other industries; the study does not offer any evidence for this proclaimed wage disparity either. Even if there is such an expectation, economic theory and history show that an adjustment in the labor market will occur because more people would want to get these higher paying jobs and employers can reduce the wages and still get the people they need.

In Global Insight (2008), the authors offer that "Research has shown that both green and conventional construction projects are being bid and worked on by similar contractors, implying that green construction work does not require specialized workers" (page 10). The research referred to is Pollin and Wicks-Lim (2008), which has not shown but rather predicted that the same people will do the green jobs in most cases. The existence of many training providers specialized in green technologies also seems to undermine this claim in Global Insight (2008).[21] There is also a contradiction with the following sentence from the same

20 www.bls.gov.

21 For a list of wind training providers, please see http://www.windustry.org/where-can-i-find-a-school-or-training-program-specific-to-renewable-energy. When one searches for "solar energy training" on the internet more than eight million results are obtained, with tens of independent training providers, universities, community colleges and others in the first few pages of results.

paragraph: "Some firms are not fully aware of some green construction techniques or the wide variety of modern materials that can be used in a given renovation project." It may be the same workers but they will have to be trained and specialized before they can do at least some of the green jobs. As such, the question of whether these are "new" jobs arises again.

Domestic content

Even if labor and manufacturing conditions were sufficient for development of domestic green industry, these conditions may still not be sufficient to establish a viable domestic industry for manufacturing alternative technology components not the least because they may not be competitive with imports from established producers. Ragwitz et al (2009) also makes the assumption that first-mover advantage would be strong and European companies can export their technologies across the globe. Most U.S. states are structuring their RPS programs to favor local economic development. In fact, this focus is quite common as observed by Ladislaw and Goldberger (2010) in their survey of green stimulus programs across several jurisdictions: "…each of the countries examined below see green stimulus as part of a larger strategic goal to be a leader in clean energy and climate-friendly technologies in the years to come." But, Chinese and Indian companies are already supplying their domestic markets and competing in other markets; and they often offer cost advantages. South Koreans and others are not far behind.[22] Although quality of their products is questioned occasionally, it is reasonable to expect that their products will be improved as these companies gain experience both domestically and internationally and increase production.

There are anywhere from 80 to 140 large wind turbine manufacturers around the world.[23] On the one hand, this statistic shows that manufacturing of wind turbines and other parts can be done in most locations with an industrial base; but on the other hand, it points to highly competitive nature of the market and difficulty of establishing and sustaining competitive advantage.

Imported technology from the green energy value chain, or renewable fuels (such as Brazilian ethanol) can be cheaper than domestically produced alternatives. In that case, forcing consumers and businesses pay more for domestically produced alternatives would reduce consumers' spending on other goods and services (substitution effect) and hurt international competitiveness of businesses, some of which will also lose sales due to reduced consumer spending. Ragwitz et al (2009) recognize all of these interactions but it is doubtful whether they or any other researchers could succeed in foreseeing the future in terms of identifying countries that will develop competitive advantage in what technology if any. This difficulty of grasping the scope of rapidly evolving green technology sphere and competing government funding is one of the fundamental challenges to any modeling exercise.

22 For example, see "Asia's green-tech rivals: Clean-energy competition in the region will be intense," *The Economist*, November 13, 2009.

23 The following web site lists 136 large wind turbine manufacturers: http://energy.sourceguides.com/businesses/byP/wRP/lwindturbine/byB/mfg/mfg.shtml. The number of main manufacturers is 88 at http://www.thewindpower.net/manufacturers.php (but some companies have been acquired or do not exist any longer).

An implicit assumption in many studies seems to be that trade barriers should be erected or protected (such as the existing ethanol import tariff) in order to ensure domestic job creation. Historically such protectionist trade policies ended up lowering the standard of living of both the country instituting such policies and potential exporters.[24] International trade implications are already being felt. Two recent examples (September 2010) illustrate the issue. Japan complained to WTO about Ontario's green energy program that requires the purchase of certain amount of supplies from domestic producers.[25] The United Steelworkers filed a complaint (5,800 pages long) with U.S. trade officials charging China with violating WTO rules by providing subsidies to its clean-energy sector and supporting it with domestic content preferences and similar policies.[26]

An interesting case study is provided by the assertion in Asmus (2008) that "Some of the biggest and most innovative energy and engineering companies in the world are willing to make massive investments in the development of California's renewable energy industry – if we only let them." There is no evidence offered to support this statement in the study. The same companies or others would be (and have been) interested in any other jurisdiction that offer business-friendly environment, tax breaks, or other benefits. Given the California's large budget deficit, its unemployment rate that is higher than national average, and net migration out of state (of people and businesses), it is difficult to see how California would be more attractive to a business than a competing location.[27] The state may have certain advantages in terms of information technology industry and some intangibles, these are not always sufficient to overcome some of the economic handicaps. These challenges are valid for any jurisdiction not just California. Economic history is full of examples of states competing with each other by adjusting the key economic levers of taxation, red tape and infrastructure. In the 1990s, California was the leader in wind installations but by the mid-2000s, Texas surpassed California and leads the U.S. with almost 10,000 MWs of installed capacity versus California's 2,700 MWs. Perhaps more importantly from the perspective of jobs, Texas has also been attracting manufacturing investment, training facilities and other businesses along the wind supply chain.

Impact on fossil fuels

One of the benefits expected from green technologies and fuels is improving energy security by reducing both the need for and the price of imported fossil fuels. Pollin et al (2008) deducts that "…because of increased U.S. investment in renewable energy and energy efficiency, then the price of oil would also fall." (page 2) There are two major issues with this statement.

First, any direct connection between oil price and renewable energy and energy efficiency requires a leap of faith. More than two thirds of oil consumed in the U.S. is consumed in

24 There is a wide literature on negative impacts of trade protectionism; Jagdish Bhagwati has been the eminent scholar in this field. In addition to his many articles, his books *Free Trade Today* (2003) and *In Defense of Globalization* (2004) provide an insightful treatment of the issues for non-academic readers.

25 http://www.theglobeandmail.com/report-on-business/ontario-clean-power-subsidies-draw-wto- challenge-from-japan/article1705239/.

26 http://online.wsj.com/article/SB10001424052748704644404575481743747170692.html.

27 For a treatment of these issues, please see http://www.economist.com/node/13990207.

the transportation sector; and this share is expected to increase.[28] In 2008, only about 5.6 percent of transportation fuels were non-petroleum (mostly ethanol).[29] Although there are developments in biofuels and electric vehicles, liquid fuels derived from oil, natural gas and even coal are expected to dominate the transportation sector.[30] Most advanced green technologies such as wind focus on power generation. Similarly, most immediate energy efficiency improvements can be done to reduce electricity use and heating needs. In the U.S., very little oil is used for power production. More oil is used for heating purposes but natural gas and electricity are more common ways to heat homes and businesses. Given these facts, one cannot establish a direct link between increased used of renewables and the demand for oil.

Second, this statement also hints to a lack of understanding of oil market dynamics. Even if one entertains the idea of rapid expansion of green technologies in the transportation sector, the impact of these developments in the U.S. on the oil price is highly uncertain. The price of oil may (and, in all likelihood, will) still increase despite larger investment in the U.S. (and other OECD countries) on alternatives. Oil market is global. Rapidly increasing demand in China, India and elsewhere, and the lack of sufficient upstream investment will dictate the long-term price of oil. For example, in its *International Energy Outlook 2010*, the EIA's low oil price scenario foresees a flat price line at about $52 per barrel in 2008 dollars; the high price scenario predicts an increasing price (in 2008 dollars) over the years reaching $210 by 2035.

OPEC members and other major exporters react to energy independence strategies in OECD by reducing investment in upstream exploration and production. Moreover, they invest in petrochemicals facilities and refineries to export products rather than crude oil. Put together, these demand and supply movements indicate sustained, if not rising, prices.[31]

Although not everyone agrees on the role of commodity and derivatives trading in financial markets, the infusion of large sums of money by non-energy players into these markets can influence the price of oil, mostly upwards as witnessed during late 2007 and early 2008. Foss et al (2009) provide an in-depth discussion of these changes in the financial oil markets and their impact on physical fundamentals.

It may be the case that "…the United States does have the ability even in the short run to dampen oil price run-ups through expanding supply, via its Strategic Petroleum Reserves" as stated in footnote 11 of Pollin et al (2008). This has been done during Hurricanes Katrina and Ivan in the past to compensate for lost output but only for several months. So, it is not "even" in the short-run but rather "only" in the short-run one can try to impact the price of oil by a

28 http://www.eia.gov/energyexplained/index.cfm?page=oil_use.

29 http://www.eia.doe.gov/cneaf/alternate/page/atftables/afv_hist_data.html.

30 Ethanol consumption has increased significantly in the last few years due to generous subsidies and banning of MTBE as an additive in gasoline. However, bottlenecks in distribution networks, environmental concerns related to fertilizer use in corn fields and rapid depletion of water in underground reservoirs are limiting further expansion of corn-ethanol in the U.S. There are many studies on this area, including Gülen and Shenoy (2008).

31 For example, see "An Inconvenient Truth about OPEC" by Anas Alhajji at http://www.europeanvoice.com/article/2010/09/an-inconvenient-truth-about-opec/68863.aspx.

release from the SPR and with no guarantees of success. Also, the amount of oil production that was temporarily lost during Katrina, 1.4 million barrels a day, was 1.6 percent of global demand. The five-percent reduction in oil demand expected in the study due to green energy will not happen as quickly; hence SPR comparison has no relevance to this discussion.

Ignored factors

There are constraints faced by these technologies such as lack of transmission capacity, difficulty of siting and building these facilities (high cost as well as NIMBY opposition to transmission facilities), technical challenges associated with reliably incorporating increasing amounts of intermittent resources such as wind and solar into grids, high cost of solar (orders of magnitude, unfortunately), and so on. These realities on the ground cannot and should not be swept aside as they can and do block development of energy projects, including renewables and transmission lines, which are necessary for rapid expansion of wind and solar.

Job creation statistics

The comparison of job creation is often based on flawed statistics as it looks at jobs per MW rather than jobs per dollar invested. An effort to correct for this bias is presented in Table 1 below for power generation. The original estimates are derived from the Kammen, Kapadia & Fripp (2004), which is a survey of dozen studies in the United States and Europe. Focus is on direct, first-round employment impacts, including additional employment from construction, manufacturing and installation of new facilities, the operations and management, and fuel-processing. The indirect, inter-industry impacts are excluded.

The 'jobs per capacity' statistic reported in column (1), jobs per megawatt, is often used to emphasize the job creation benefits of "green" technologies. Kammen, Kapadia & Fripp (2004) adjusted the capacity based on the capacity factor, calling it megawatts averaged over the year, or MWa. For example, if a solar PV facility is used about 21 percent of the time, each installed megawatt would be equivalent to 0.21 MWa. Similarly, they adjusted coal, natural gas, wind and biomass generation using 80 percent, 85 percent, 35 percent and 85 percent, respectively.

This statistic indicates that solar PV creates the most jobs per used capacity. But clearly this statistic is misleading as it is turning the inherent disadvantage of these technologies (i.e., low capacity factor) into an advantage; it inflates jobs for technologies with low capacity factor. The cost of electricity is a more relevant criterion from consumers' and the economy's perspective. A correction is offered by Huntington (2009) by looking at jobs per dollar spent on electricity as reported in column (3), which is obtained by dividing column (2), jobs per electricity generation, by column (4), cost of electricity from each type of generator.

Table 1. Job Creation Associated With Different Generation Technologies

	(1)	(2)	(3)	(4)
	Jobs/MWa	Jobs/GWh	Jobs/$MM	$/KWh
Solar PV (Low)	7.41	0.846	3.18	$0.2664
Solar PV	10.56	1.205	4.53	$0.2664
Wind (Low)	0.71	0.081	1.64 / 1.16	$0.0495 / $0.07
Wind	2.79	0.318	6.43 / 4.54	$0.0495 / $0.07
Biomass (Low)	0.78	0.089	1.80	$0.0496
Biomass	2.84	0.324	6.54	$0.0496
Coal	1.01	0.115	3.72	$0.0310
Natural Gas	0.95	0.108	2.05	$0.0529

Explanation:
Column (1), source: Kammen, Kapadia & Fripp (2004).
Column (2) = column (1) * (10^6) / 8760.
Column (3) = column (2) / column (4).
Column (4), source: Metcalf (2006), converted from cents per KWh.

MW = megawatts = capacity.
GWh = MWa x 1000 x 8760.

Source: Huntington (2009).

Now the differences between green technologies and conventional ones are not that significant although high end estimates for green technologies are still higher. There are varying estimates about the cost of electricity from wind and solar. Also, there has been cost inflation in recent years and costs differ by project and region (Wiser and Bolinger, 2010). It is possible to see wind prices of 6-7 cents per kWh. If one uses 7 cents figure, the jobs created by wind per dollar will decline (second values reported for wind in column (3) of Table 1). Important to note is that if the cost of renewable technologies decline (which may be due to lower labor cost associated with higher productivity), they will become more attractive and gain market share on their own merit (in the absence of any other problems associated with intermittency), rendering the focus on green jobs distractive rather than helpful.

Opportunity cost

The opportunity cost of "green" investment is almost always ignored in green jobs studies. When a dollar is invested in alternative technologies, the same dollar is not available for other sectors. When governments provide subsidies, grants, or tax breaks to expand more expensive technologies, be it renewables or nuclear, resources need to shift away from other sectors in the economy. If the purpose of investing is to create jobs, there are other sectors where the money could be spent more productively. As compared to the overall economy and some sectors in particular, investment in energy projects lead to job losses (Figure 2). "Net jobs" is the difference between jobs created with incentives in each activity minus US BEA estimates of jobs normally created per $1 million invested but that are lost due to diverted investment.

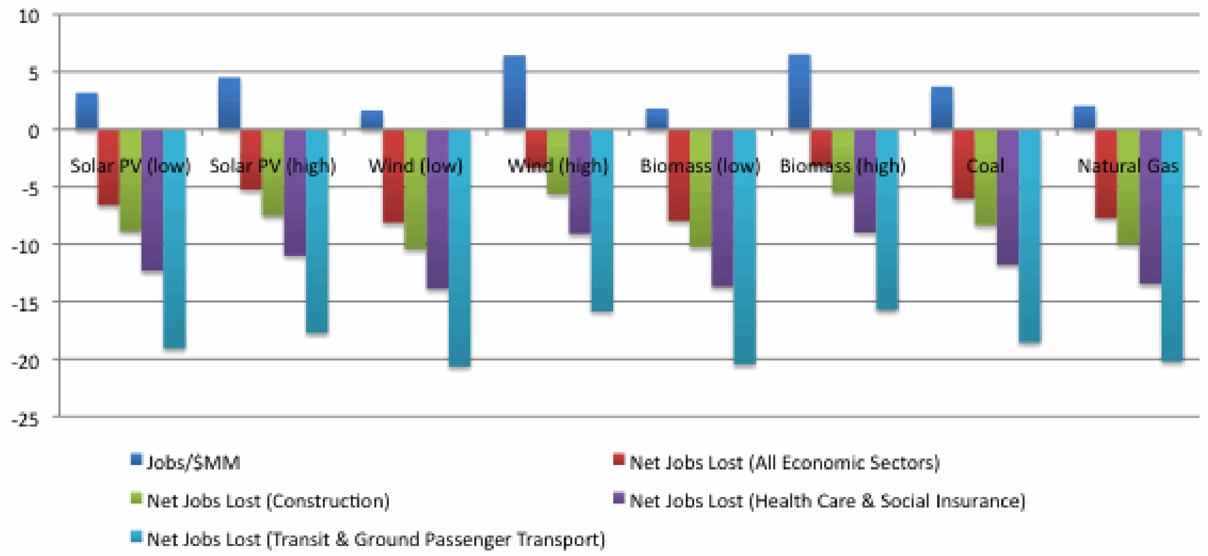


Figure 2. Jobs lost due to diverted investment
Source: Huntington (2009).

Although it is a study that has been criticized by environmental groups and green industry associations, it is worth noting that Alvarez et al (2009) reached similar conclusions following a similar approach when they considered opportunity cost, which is important to capture especially when green jobs are promoted as a solution to economic slow-down. The study concluded that more than two jobs will be lost for every green job created if a country followed Spain's strategy to promote renewables due to increased cost of energy in addition to the opportunity cost of private capital invested in renewables instead of other more productive sectors. Spain's decision to limit support to new facilities and its attempt to cut tariff on existing plants, which is rejected so far, provide support to findings of Alvarez et al (2009).[32] Nevertheless, as pointed out by Lantz and Tegen (2009), more details on the approach and data used in the analysis would help since the statistics used are not commonly seen in the literature. For example, in Chapter 4 of Alvarez et al (2009), two statistics are offered: (1) the ratio of subsidy to renewables per worker to average capital per worker; and (2) the ratio of annual subsidy to renewables per worker to average productivity per worker. If direct and indirect jobs created by the renewable industry are compared to direct, indirect and induced jobs by private capital, this would bias the results against renewables as claimed by Lantz and Tegen (2009). It would have been desirable for Alvarez et al (2009) to provide further discussion on these statistics and their sources of data and any calibrations they applied to raw data.

On the other hand, Lantz and Tegen (2009) also fall into the trap of counting on export potential as a way of creating jobs. As discussed in detail elsewhere in this report, increasing global competition for renewable technology development and manufacturing, and associated protectionist measures render export potential argument doubtful at best, outright wrong in all likelihood. Even in their critique, they can only refer to revenues from the export of wind turbines, which does not directly translate into jobs created and does not undermine the thesis of Alvarez et al (2009) that investment in private sector is more productive than investment in renewables.

32 For a discussion of recent challenges faced by renewable support programs in Europe, see Osborne (2010).

Another useful comparison is provided by Geoffrey Styles in his Energy outlook blog.[33] Styles compares the average energy production by the oil and gas industry to that from green industries. According to Styles' calculations 1.8 million employed in the oil and gas industry value chain, including service station employees supplied 33 quadrillion Btus of energy in 2007 (a third of total US energy consumption and 46 percent of US energy production), which translates to 18.6 billion Btus per worker. Using 36 billion gallons per year of biofuel targeted for 2022 under the federally-mandated Renewable Fuel Standard with the 20 percent of net electricity generation from wind by 2030 posited by a recent DOE study, the total equates to roughly 14 quads per year (assuming capacity factors for renewables much higher than actual 20-40 percent range). Divided by the large employment figures mentioned by candidates Obama and McCain or those proclaimed by some of the studies (5 million), this translates to 2.8 billion Btus per green energy worker. In other words, green workers will have one sixth of productivity of the oil and gas industry worker. Styles also converts the productivity gap into dollars, assuming average US wage of $47,000 per year. He concludes that effective energy cost of the green scenario will be $100 per barrel, before considering capital expenses. Using the above figures, the comparable calculated labor expense for oil and gas is around $15 per barrel.

Concluding remarks

Alternative energy technologies, energy efficiency and conservation and other environmentally friendly programs have benefits ranging from lower emissions to enhanced energy security, albeit at different levels for different technologies or approaches. But adding "net jobs" cannot be defended as another benefit of investing in these technologies. Models can be developed to analyze alternative scenarios that can show net job gains over a certain period of time but these are based on aggressive and unrealistic assumptions of continuous and fast technological innovation, rapid progression of economies of scale, global implementation of similar green policies, adoption of protectionist measures such as tariffs or local content requirements and others.

However, the realities of the global energy scene are:

- Most green technologies are far away from the scale that is needed to replace conventional fuels in a significant way. Although it is reasonable to expect improvements in technology and cost structure in the future, it is difficult to predict the development path that can be included in modeling exercises.
- These technologies are more expensive than conventional technologies and hence need subsidies, tax incentives and mandates to gain market share (some more than others). A carbon tax could level the playing field for wind at about $20-30 per ton but needs to be much higher for solar and other technologies.

33 http://energyoutlook.blogspot.com/2008_10_01_archive.html.

- They face integration problems due to their intermittency, immaturity of technology, scalability limits, inability to communicate with existing infrastructure, and other technical or power market economics constraints.
- Consumers, especially at the residential level, are often reluctant to adopt new technologies if they are not certain they will get the same benefits as those from current technologies and even more reluctant when it comes to changing their energy consumption behavior, which is often based on habit rather than conscious decision making.
- Pushing aggressively to increase the share of these technologies, though clearly possible, will cost large sums of money and will increase cost of energy to society, negatively impacting purchasing power, employment and GDP.

One cannot simply wish these realities away.

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Appendix

EmployRES The impact of renewable energy policy on economic growth and employment in the European Union.

Ragwitz, Mario, Wolfgang Schade, Barbara Breitschopf, Rainer Walz, Nicki Helfrich (Fraunhofer ISI, Germany), Max Rathmann (Ecofys, the Netherlands), Gustav Resch, Christian Panzer, Thomas Faber, Reinhard Hass (Energy Economics Group, Austria), Carsten Nathani, Matthias Holzhey (Rütter + Partner Socioeconomic Research + Consulting, Switzerland), Inga Konstantinaviciute (Lithuanian Energy Institute, Lithuania), Paul Zagamé, Arnaud Fougeyrollas, Boris le Hir (Société Européenne d'Économie, France), April 2009.

This report concerns the RES policy in the European Union; and tries to resolve the debate regarding the question of whether the RES policy will lead to net job creation or net job loss. Naturally, given the complex nature of economic systems and labor markets, different assumptions about labor intensity of different industries (in particular different renewable technologies), size of distribution and budget effects, and multiplier effects can lead to either outcome. Hence, it is important to have a robust and realistic modeling framework, and good data on key input variables; and to undertake rigorous reality checking.

This study delivers on these points, for the most part. It presents one of the most comprehensive studies to evaluate economic impacts (growth and employment) of renewable energy mandates, combining several approaches. In addition to linking several databases and models, which appear to be well tested, the authors involved stakeholder consultation and peer review, holding two workshops to confirm that their assumptions are consistent with experience out in the real world. But, there is no list of stakeholders and peers, or their institutions; so it is difficult to judge the effectiveness of this consultation and review processes.

In terms of models, the bottom-up models they use are appropriate to capture details of each technology, and in fact, GREEN-X is created as a tool to facilitate optimal strategies of increasing share of renewable energy. The historic cost data for renewables obtained from the GREEN-X model are fed into the MULTIREG model. This static input-output model will not be able to capture longer term dynamics; IO coefficients will change as economies evolve. Another potential issue is the use of IO tables of "similar" countries for those countries with no IO tables. The criteria used to decide which countries were "similar" are not revealed in the study.

The outputs of these static input-output models are then linked to a simulation model to estimate future RES investments and then they are all inputted into two macroeconomic models, NEMESIS and ASTRA, to estimate future economic impacts.

The discussion of both negative and positive effects of RES policies is detailed and balanced, and the conclusions capture this balance: "Despite the large gross figures in terms of employment and value added, net figures are significantly smaller due to replaced investments in conventional energy technologies as well as due to the dampening effect of the higher cost of renewable energies compared with conventional alternatives." (p. 195)

Despite rigorous work and detailed presentation of the report, there is a fundamental issue that applies to all such studies. Regardless of the modeling tools chosen, conclusions of any such study depend on the assumptions. In this regard, this study may be making some unrealistic assumptions.

Some of the assumptions related to RES replacing conventional fuels may need to be revisited; some experience in the U.S. indicate that intermittent nature of wind is forcing gas and even coal units to cycle throughout the day. Although overall fossil fuel consumption may still go down with more RES, electricity grids may need to maintain existing and/or invest in new fossil fuel plants to provide reliability service. The impact of integrating larger amounts of intermittent resources is a potential area that may undermine typical substitution assumptions of modelers.

The use of a default weighted average cost of capital at the rate of 6.5 percent can also be an issue as it reduces the long-run marginal cost of RES technologies but it may not be realistic if financing will have to be done from private capital.

However, most problematic is the export growth assumption. It is clear that future export opportunities are an important reason for future RES investment in the EU to be as large as this study assumes: "Currently the strong investment impulses - based on installations in Europe and exports to the rest of the world - dominate the economic impact of renewable energy policies and therefore lead to positive overall effects" (p. 195). The authors acknowledge that "…it will be necessary to uphold and improve the competitive position of European manufacturers of RES technology and to reduce the costs of renewable energies… it will be of key relevance to improve the international framework conditions for renewable energies in order to create large markets, exploit economies of scale and accelerate research and development" (p. 195).

The world is already very competitive when it comes to these technologies. As stated in the main body of this report, many countries and even jurisdictions within a country support local development of renewable technologies and manufacturing via regulations, tax incentives, import tariffs and other means. There is an increasing number of complaints at the World Trade Organization regarding unfair protection of domestic renewable or green industries. These cases at the WTO will not necessarily lead to quick removal of these protectionist measures; the U.S. maintained tariffs on imported ethanol for a long time despite external and internal complaints, and Chinese, Indians and others will continue to support their domestic industries, and in some cases such as biofuels from agricultural products, they may have a competitive advantage. In any event, biofuels are likely to be more vigorously defended by tariffs and other policies because they create additional income opportunities for the agricultural sector, which often has a special place in many countries' politics and possibly many people's hearts, and they are more labor intensive. Interestingly most detailed modeling exercises from different jurisdictions seem to make similar assumptions about export growth or protection and/or encouragement of domestic industry, perhaps sometimes not recognizing contradictory "beggar thy neighbor" effect of these assumptions.

As a final example to emphasize how shaky the ground on which this export potential argument stands is, let us look at Vestas. The Danish wind manufacturer is probably still the largest producer of windmills and related products but their market share has been shrinking: it fell from about 6.1 percent of MWs installed in 2001 to about 4.5 percent in 2008 (the share of Vestas employment in global wind industry employment has also fallen about the same rate).[34] In 1995, Vestas' market share was about 20-25 percent. Note that a Reuters article, referring to a study by the BTM Consult (a leading independent consultancy on wind energy), provided Vestas' market share as 12.5 percent in 2009 followed by GE with 12.4 percent.[35] The same article also stated that "[t]he most significant change in the supply market in 2009 was the strong growth of Chinese wind turbine manufacturers, three of which were among the Top-10 suppliers." There are now many more competitive wind companies globally (more than 130 large wind turbine manufacturers around the world according to one web site).[36]

Given these realities, it is difficult to justify assumptions that give EU companies a competitive advantage to export their green technologies. It is more difficult to assume that EU companies will be able to maintain their current market share in the future.

It would be interesting to repeat this modeling exercise with lower levels of exports.

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34 Calculated based on *World Wind Energy Report 2009* by World Wind Energy Association (http://www.wwindea.org/home/images/stories/worldwindenergyreport2009_s.pdf) and Vestas web site (http://www.vestas.com/en/about-vestas/history.aspx).

35 "China became top wind market in 2009", Reuters, March 29, 2010 (http://www.reuters.com/article/idUSTRE62S12620100329).

36 http://energy.sourceguides.com/businesses/byP/wRP/lwindturbine/byB/mfg/mfg.shtml. The number of main manufacturers is 88 (but some companies have been acquired or do not exist any longer) at http://www.thewindpower.net/manufacturers.php.