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Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?

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1. Authors' e-mail addresses have been updated.
2. Total person-yrs/GWh for O&M and fuel processing, for the Wind 2 technology in Table 2 has been corrected to read 0.03 (instead of 0.78).
3. Employment under Scenario 1 in Table ES-2, Table 3 and Figure 1 has been corrected as follows: O&M and Fuel Processing: 111,136 (instead of 188,317) and Total Employment: 163,669 (instead of 240,850).
4. The contents of Appendix 2 were printed with the Appendix 3 heading in the original publication, giving the impression that Appendix 2 was missing. Appendix 2 has the correct heading in this version.

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PUTTING RENEWABLES TO WORK:

HOW MANY JOBS CAN THE CLEAN ENERGY INDUSTRY GENERATE?

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OVERVIEW

Expanding the use of renewable energy is not only good for our energy self-sufficiency and the environment; it also has a significant positive impact on employment. This is the conclusion of 13 independent reports and studies that analyze the economic and employment impacts of the clean energy industry in the United States and Europe. These studies employ a wide range of methods, which adds credence to the findings, but at the same time makes a direct comparison of the numbers difficult. In addition to reviewing and comparing these studies, we have examined the assumptions used in each case, and developed a job creation model which shows their implications for employment under several future energy scenarios.

Energy Technology	Source of Estimate	Average Employment Over Life of Facility (jobs/MWa)		
		Construction, Manufacturing, Installation	O&M and fuel processing	Total Employment
PV 1	REPP, 2001	6.21	1.20	7.41
PV 2	Greenpeace, 2001	5.76	4.80	10.56
Wind 1	REPP, 2001	0.43	0.27	0.71
Wind 2	EWEA/Greenpeace, 2003	2.51	0.27	2.79
Biomass – high estimate	REPP, 2001	0.40	2.44	2.84
Biomass – low estimate	REPP, 2001	0.40	0.38	0.78
Coal	REPP, 2001	0.27	0.74	1.01
Gas	Kammen, from REPP, 2001; CALPIRG, 2003; BLS, 2004	0.25	0.70	0.95

Table ES–1: Average employment for different energy technologies. “MWa” refers to average installed megawatts de-rated by the capacity factor of the technology; for a 1 MW solar facility operating on average 21% of the time, the power output would be 0.21 MWa. References in parentheses and sources refer to the studies reviewed in the text.

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Scenarios	Average employment associated with each scenario (jobs)		
	Construction, Manufacturing, Installation	O&M and Fuel Processing	Total Employment
Scenario 1: 20% Renewable Portfolio Standard (RPS) by 2020 (85% biomass, 14% wind energy, 1% solar PV)	52,533	111,136	163,669
Scenario 2: 20% Renewable Portfolio Standard (RPS) by 2020 (60% biomass, 37% wind energy, 3% solar PV)	85,008	91,436	176,444
Scenario 3: 20% Renewable Portfolio Standard (RPS) by 2020 (40% biomass, 55% wind energy, 5% solar PV)	111,879	76,139	188,018
Scenario 4: Fossil Fuels as Usual to 2020 (50% coal and 50% natural gas)	22,711	63,657	86,369
Scenario 5: 20% Gas Intensive by 2020 (100% natural gas)	22,023	61,964	83,987

Table ES–2: Comparison of the estimated employment created by meeting the equivalent of 20 percent of current U.S. electricity demand via and expansion of fossil or renewables-based electricity generation.

A key result emerges from our work: Across a broad range of scenarios, the renewable energy sector generates more jobs than the fossil fuel-based energy sector per unit of energy delivered (i.e., per average megawatt).

In addition we find that the employment rate in fossil fuel-related industries has been declining steadily for reasons that have little to do with environmental regulation. Finally, we find that supporting renewables within a comprehensive and coordinated energy policy that also supports energy efficiency and sustainable transportation will yield far greater employment benefits than supporting one or two of these sectors separately. While certain sectors of the economy may be net losers, policy interventions can help minimize the impact of a transition from the current fossil fuel dominated economy to a more balanced portfolio that includes significant amounts of clean energy. Further, generating local employment through the deployment of local and sustainable energy technologies is an important and underutilized way to enhance national security and international stability.

INTRODUCTION

It is often assumed that environmental protection inevitably comes at a financial cost. However, an increasing number of studies are finding precisely the opposite is true in the case of renewable energy: that greater use of renewable energy systems provides economic benefits through investments in innovation, and through new job creation, while at the same time protecting the economy from political and economic risks associated with over-dependence on too limited a suite of energy technologies and fuels.

This report reviews the range of recent studies on the job creation potential of the renewable energy industry. We critically analyze the studies with a view to answering four main questions:

- How can one compare and make sense of employment impact numbers derived through different methods, and presented in different units?
- What are the potential regional employment impacts of large-scale growth in the renewable energy sector?
- What would large-scale growth in the renewable energy sector mean for those employed in the fossil fuel energy sector?
- What policy measures would maximize the net positive economic and employment benefits that the renewable energy industry offers?

A summary of all studies reviewed, and methods used therein, is provided in Appendix 1. While a simple analytic comparison across studies is difficult for reasons discussed below, we can still draw a number of clear general conclusions:

- The renewable energy sector generates more jobs per megawatt of power installed, per unit of energy produced, and per dollar of investment, than the fossil fuel-based energy sector.
- Jobs in the fossil fuel sector are declining for reasons that are, for the most part, not related to environmental regulations. Nevertheless, a shift from fossil fuels to renewables in the energy sector, at whatever scale, will create some job losses. These losses can be adequately mitigated/ameliorated/alleviated through a number of policy actions.
- Embedding support for renewables in a larger policy context of support for energy efficiency, green building standards, and sustainable transportation will greatly enhance net positive impacts on the economy, employment and the environment.

RENEWABLE ENERGY AND JOBS: KEY ISSUES

We now return to the four questions, and address each in some detail.

How can one compare and make sense of employment impact numbers derived through different methods, and presented in different units?

The studies reviewed use different basic methods and models, and often report employment impacts in different units, which can make comparison difficult. In this section we discuss: a) different ways to derive employment figures for the energy sector, focusing on methods of analysis, and ways of reporting employment impacts; and b) the framework and format we use to provide comparisons for employment across different technologies.

Calculating employment from renewables: methods of analysis

Table 1 contains a list of the studies reviewed. Additional details on each study are compiled in Appendix I.

Number	Year	Author	Study (model type)
1	2004	The Institute for America's Future, The Center On Wisconsin Strategy and The Perryman Group, Waco TX.	The Apollo Jobs Report: For Good Jobs & Energy Independence New Energy for America (I-O model)
2	2003	Greenpeace/European Wind Energy Association	Wind Force 12. A Blueprint to Achieve 12% of the World's Electricity from Wind Power by 2020. (Analytical model)
3	2003	Environment California Research and Policy Center (Brad Heavner and Bernadette Del Chiaro)	Renewable Energy and Jobs. Employment Impacts of Developing Markets for Renewables in California (Analytical model)
4	2002	CALPIRG (Brad Heavner and Susannah Churchill)	Renewables Work.Job Growth from Renewable Energy Development in California (Analytical model)
5	2001	World Wide Fund for Nature (Study conducted by Tellus Institute and MRG Associates)	Clean Energy: Jobs for America's Future (I-O model)
6	2001	Renewable Energy Policy Project (co-authored by Virender Singh of REPP and Jeffrey Fehrs of BBC Research and Consulting)	The Work that Goes into Renewable Energy (Analytical model)
7	2001	Daniel Kammen and Kamal Kapadia, Energy and Resources Group, University of California, Berkeley	Jobs from Renewables, study for Kerry/Kennedy (Analytical model)
8	2001	Greenpeace	2 Million Jobs by 2020. Solar Generation. Solar Electricity for over 1 billion people and 2 million jobs by 2020. (Analytical model)
9	2001	Environmental Law & Policy Center (study done by the Regional Economics Applications Laboratory: Geoffrey Hewings and Moshe Yanai)	Job Jolt: The Economic Impact of *Repowering the Midwest. A Clean Energy Development Plan for the Heartland (I-O model)*
10	2000	Michael Renner, Worldwatch Institute	Working for the Environment: A Growing Source of Jobs (Worldwatch Paper 152)
11	1999	European Wind Energy Association/European Commission Directorate-General for Energy	Wind Energy: The Facts (Analytical model)
12	1999	European Commission/ALTENER Programme DG for Energy and Transport	Meeting the Targets and Putting Renewables to Work (I-O model)
13	1998	Skip Laitner, Stephen Bernow, John DeCicco	"Employment and other macroeconomic benefits of an innovation-led climate strategy for the United States." *Energy Policy* 26, 5: 425-432. (I-O model)

Table 1: List of studies reviewed.

Studies that focus on calculating the employment impacts of the renewables industry can be divided into two main types: a) those that use input-output (I-O) models of the economy; and b) those that use simpler, largely spreadsheet-based analytical models. Among the studies reviewed and listed in Table 1, reports number 1, 5, 9, 12 and 13 are based on I-O models, and the rest are based on analytical models. Analytical models typically only calculate direct employment impacts. *Direct employment* includes those jobs created in the manufacturing, delivery, construction/installation, project management and operation and maintenance (O&M) of the different components of the technology, or power plant, under consideration. I-O models calculate direct employment but also account for *indirect jobs* that are induced through multiplier effects of the industry under consideration. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. I-O models capture such multiplier effects, as well as the economic impacts of spending by workers in the new jobs. Both types of models have advantages and disadvantages.

I-O models provide the most complete picture of the economy as a whole. They capture employment multiplier effects, as well as the macroeconomic impacts of shifts between sectors; that is to say, they account for losses in one sector (e.g. coal mining) created by the growth of another sector (e.g. the wind energy industry). Analytical models generally ignore these multiplier effects, and are more likely to under-report overall employment impacts.

The disadvantage of I-O models is that they can be opaque, and make a number of assumptions in order to reach a high level of aggregation. All the I-O based studies we reviewed model the impacts of an entire suite of clean energy policies – including renewable portfolio standards, energy efficiency programs, and policies for sustainable transportation – and present impacts on the economy as aggregated net results. Only in one case (the Apollo Jobs Report; see study **1** in Appendix 1) are the employment and economic impacts attributed to separate policy categories such as “strengthening the renewables market,” “bio-energy resource development” and “fuel cell R&D and deployment.” Even in this report, however, each of these categories includes a suite of specific policies, whose individual impacts are impossible to discern. It is also generally impossible to calculate employment generated by different technology types such as solar PV and wind energy within a larger I-O model, nor are there employment numbers for the fossil fuel industry to draw comparisons with.

Further, all of the studies model only one “idealized” scenario. This makes it is impossible to gauge the effects of alternative policy scenarios (short of actually getting hold of the model itself), or the impact of even slight deviations from the reported scenario. For example, in the WWF study[1], while all states are net winners under the scenario they present, some states are projected to gain as few as 2,600 jobs (in North Dakota) by 2020 (despite being a state with a tremendous wind-energy resource). It is entirely possible that small differences in only a few parameters could turn these job gains to net losses. It is not possible to know which specific set of policies are creating those jobs for each state, nor can one tell what would happen to projected employment in a particular state should one or more policies be implemented in a different form from what is recommended in the report. In comparison, the analytical models are much more transparent. The assumptions are clear, and it is possible for the reader to conduct sensitivity analyses (like changing the nature and types of policy support to see how impacts may change) on their results.

[1] See study **5** in Appendix 1

Reporting employment impacts

Distinguishing between jobs in manufacturing, construction and installations vs. jobs in operations and maintenance, fuel production, extraction and processing

Most of the reports summarized here distinguish between employment in manufacturing/construction and in O&M/fuel processing. However, none of them discuss the policy implications of the different kinds of jobs created by different energy technologies or facilities, which we believe to be important. While the majority of jobs in the fossil fuel industry are in fuel processing, and operations and maintenance (O&M) (see Table 1), the majority of jobs created in the renewable energy industry are in manufacturing and construction. Biomass energy is an exception, where the majority of jobs are also in fuel production and processing (in agriculture), and O&M.

Paying attention to the types of jobs created is especially important for regional and state-level policy. For a particular state or region, even if total person-yrs lost in the fossil fuel energy sector are counterbalanced by total person-yrs gained in the renewable energy industry, the actual shift may be from jobs in O&M, to jobs in manufacturing. It is important to know therefore what *type* of jobs are being lost, and what type created, to determine what sorts of retraining and retooling programs one would need to make sure that jobs remain in the state.

Making the distinction between these two kinds of jobs is also important because the categories ‘scale’ differently as the industry expands. For example, an expansion of the U.S. PV industry could also lead to the manufacture of more renewable energy system components for export. This would create additional jobs in manufacturing, but no corresponding jobs in O&M.

Most studies report jobs in manufacturing and construction in terms of “person-years per MW,” i.e., the amount of labor required to manufacture equipment or build a power plant which can deliver a maximum of one megawatt of power[2]. In contrast, jobs in O&M and fuel processing are usually reported in terms of “jobs per MW,” i.e., the number of people who will need to be employed continuously to provide for the ongoing operation of a plant with a maximum output of one megawatt.

In order to calculate the total employment associated with each energy technology, it is necessary to put these job numbers on a common basis and add them together. To do this, we converted the manufacturing and installation jobs (person-years per MW) into jobs per MW by averaging this type of employment over the life of the facility. For example, if it takes 32.3 person-years to make and install one megawatt of solar photovoltaic modules[3], and the modules last 25 years, then this technology will give employment to an average of 32.3 ÷ 25 = 1.3 persons in the manufacturing and installation sector over the lifetime of the modules. In reality, manufacturing and installation jobs are concentrated at the beginning of the life of each facility; however, if many facilities of a given type are being built (and eventually replaced) throughout the economy, then this average employment number will indicate the ongoing manufacturing and installation employment that results from these facilities. Once manufacturing and installation jobs have been converted to average values over the life of the energy equipment (in job-years per MW-year, or jobs per MW), it is a simple matter to add to this the ongoing employment required to fuel and operate the equipment (also measured in jobs per MW). The total

[2] This is a simplification. Most commercial power plants have peak outputs of hundreds of megawatts. In that case, the total labor used to build the larger plant is divided by the maximum output of the plant.

[3] Source: REPP Report. See study **6** in Appendix 1.

employment values which we then report can be seen either as the simple average employment over the life of the first set of energy facilities built under a given policy scenario, or as the steady-state employment that will result from installing (and eventually replacing) those facilities in perpetuity.

Jobs per peak megawatt vs. jobs per average megawatt
Another important issue in reporting employment across different energy technologies has to do with whether one calculates jobs per peak (or nameplate) megawatt (MWp), or jobs per average megawatt (MWa). None of the studies surveyed treat this issue adequately. Once again, understanding the differences between these two ways of reporting employment holds implications for policy. This is especially relevant when we are trying to compare employment across different energy technologies.

Suppose we are interested in implementing a policy under which 20% of the electricity ***produced*** in the United States comes from renewable energy sources. This is not the same as saying that 20% of the ***installed energy capacity*** should be renewable. Since it is the actual production of energy that causes environmental problems like global warming or acid precipitation, it makes more sense to think of the renewables/fossil fuel mix in terms of energy produced rather than energy capacity installed. But one megawatt of installed coal capacity does not produce the same amount of electricity as one megawatt of installed solar panels, for instance. A coal power plant is likely to operate for 80% of the time (the rest of the time it is likely to be shut down for maintenance), so one megawatt of installed coal capacity will produce 1MW x 0.8 x 24 hrs/day = 19.2 megawatt-hours (MWh) of electricity over one day. In comparison, a solar array of 1MW capacity will only operate for as many hours as the sun shines. On average, there is the equivalent of five hours of peak sunshine in one day in the US. So the capacity factor for solar PV is 5hr/24hrs = 21%. One megawatt of solar PV will therefore produce on average 1 MW x 0.21 x 24hrs/day = 5 MWh of electricity in one day. In other words, the same nameplate (or peak) capacity of coal and solar PV (1MWp) will produce very different amounts of electricity over a day; the coal facility will produce 19.2MWh, while the solar PV panel will produce 5 MWh per day.

Therefore, to get the same amount of electricity from a solar PV module as from a coal facility, we need about four times more capacity (MWp) of solar PV (i.e. 19.2MWh/5MWh) than of coal capacity (MWp). To account for this, we convert nameplate or peak capacities (MWp) for each energy technology into an average capacity value (MWa), which indicates the average power output that can be expected from that technology over the course of a year. The average megawatt rating puts all technologies on an equal footing. Peak capacities (MWp) are converted to average capacities (MWa) by multiplying the MWp rating by the capacity factor for the technology under consideration (e.g., a 1 MWp solar plant would be counted as 0.21 MWa, while a 1 MWp coal plant would be counted as 0.80 MWa). Conversely, employment per MWp can be converted to employment per MWa by *dividing* by the capacity factor (since power appears in the denominator of these calculations).

It is not possible to directly compare jobs per MWp or jobs per MWa across all the studies, since the assumptions, and types of scenarios modeled vary significantly. Some studies only include direct jobs while others include both. Further, most studies do not report jobs by individual technology type. Given these limitations, we need a more consistent method to understand how jobs from renewables compare with jobs from the fossil fuel sector across technologies, and between manufacturing, construction and installation, and operation, maintenance and fuel extraction and processing.

The numbers provided in three reports (REPP, 2001; Greenpeace, 2001 and Greenpeace/EWEA, 2003[4]) allow us to develop simple scenarios to accomplish this. The results presented in Table 2 demonstrate that:

a) Every technology in the renewables industry generates more jobs per average megawatt of power in the construction, manufacturing and installation sectors, as compared to the coal and natural gas industry.
b) There is not such a clear distinction between fossil-fuel and renewable technologies in the number of jobs created in O&M and fuel processing. Reliable, low-maintenance wind turbines are estimated to require fewer jobs to operate than are needed to fuel and operate coal and gas plants. However, more jobs are created in O&M of PV systems than in the O&M and fuel processing for coal and gas plants, while biomass plants may create more or fewer jobs in O&M and fuel processing than do coal or gas plants, depending on the way biomass collection is organized.

Table 2 allows for a simple comparison between the jobs created per unit of power delivered from each energy technology. However, it is unlikely that the nation's electricity supply will ever rely on any single technology. So a better way to compare employment generation across technologies is to create scenarios that allow us to compare a range of realistic and feasible combinations of renewable and fossil fuel energy sources.

To do this, we have built five scenarios. In scenarios 1–3, we assume a 20 percent Renewable Portfolio Standard (RPS) will be achieved by 2020. The mix of renewables (exclusive of hydro) used to meet the RPS in these scenarios is varied as follows:

Scenario 1: The renewables mix stays approximately the same as it is in 2002; biomass energy (wood and waste electricity) makes up 85% of the RPS, wind energy contributes 14%, and solar PV 1%.

Scenario 2: The proportion of biomass energy is decreased from its current contribution to 60% of the RPS, wind energy constitutes 37%, and solar PV 3% of the RPS.

Scenario 3: We decrease the contribution from biomass energy even further to 40% of the RPS, wind energy now dominates at 55%, and solar PV is at 5% of the RPS.

In scenarios 4 and 5, we assume that all the electricity that would be produced by renewables under a 20 percent RPS by 2020 is produced instead by fossil fuels. We include two scenarios:

Scenario 4: Coal-powered electricity contributes 50% to the mix, and natural gas the other 50%. (i.e., coal makes up 50% and gas the other 50% of the 20% of the total electricity generated in 2020 that we previously assumed to come from renewables)

Scenario 5: Natural Gas constitutes 100% of the electricity mix (i.e., 100% of 20% of the total electricity generated in 2020 that we previously assumed to come from renewables).

[4] Studies **6, 8** and **11** in Appendix 1.

To facilitate comparison, we have considered jobs in the manufacturing, construction and installation sector, as well as jobs in the O&M and fuel-processing sector. A summary of results of the modeling exercise are presented in Table 3, and represented graphically in Figure 1. In Appendix 2, we provide a more detailed discussion of the assumptions and sources used in this modeling exercise. However, two of these assumptions bear mention here:

a) Our RPS is highly simplified, assuming that electricity production in 2020 is the same as in 2002. One interpretation of this assumption could be that energy efficiency measures will offset any growth in total electricity demand.
b) Our scenarios do not account for learning effects that may occur in these industries, nor for employment that may result from manufacturing energy equipment for export.

We believe these assumptions are compatible with the purpose of this model, which is to compare ***indicative*** employment figures across technologies, in terms of ***average employment over the lifetime of facilities***.

The results show that that in all cases, the RPS produces more jobs in manufacturing, construction and installation, as well as in O&M and fuel production and processing, than the corresponding fossil-fuel scenarios.

work-hrs per year	2000	Capacity Factor	Equip-ment lifetime (years)	Employment Components			Average Employment Over Life of Facility					
							Total jobs/MWp		Total jobs/MWa		Total person-yrs/GWh	
Energy Technology	Source of Numbers			Construction, Manufac-turing and Installation (person-yr/MWp)	Operation and Maintenance (jobs/MWp)	Fuel extraction and processing (person-yrs/GWh)	Construction, Manufac-turing, Installation	O&M and fuel processing	Construction, Manufac-turing, Installation	O&M and fuel processing	Construction, Manufac-turing, Installation	O&M and fuel processing
PV 1	REPP, 2001	21%	25	32.33	0.25	0	1.29	0.25	6.21	1.20	0.71	0.14
PV 2	Greenpeace, 2001	21%	25	30.00	1.00	0	1.20	1.00	5.76	4.80	0.66	0.55
Wind 1	REPP, 2001	35%	25	3.80	0.10	0	0.15	0.10	0.43	0.27	0.05	0.03
Wind 2	EWEA/Green-peace, 2003	35%	25	22.00	0.10	0	0.88	0.10	2.51	0.27	0.29	0.03
Biomass – high estimate	REPP, 2001	85%	25	8.50	0.44	0.22	0.34	2.08	0.40	2.44	0.05	0.28
Biomass – low estimate	REPP, 2001	85%	25	8.50	0.04	0.04	0.34	0.32	0.40	0.38	0.05	0.04
Coal	REPP, 2001	80%	40	8.50	0.18	0.06	0.21	0.59	0.27	0.74	0.03	0.08
Gas	Kammen, from REPP, 2001; CALPIRG, 2003; BLS, 2004	85%	40	8.50	0.10	0.07	0.21	0.60	0.25	0.70	0.03	0.08

Table 2: Comparison of jobs/MWp, jobs/MWa and person-yrs/GWh across technologies.

Scenarios	Average employment associated with each scenario (jobs)		
	Construction, Manufacturing, Installation	O&M and Fuel Processing	Total Employment
Scenario 1: 20% Renewable Portfolio Standard (RPS) by 2020 (85% biomass, 14% wind energy, 1% solar PV)	52,533	111,136	163,669
Scenario 2: 20% Renewable Portfolio Standard (RPS) by 2020 (60% biomass, 37% wind energy, 3% solar PV)	85,008	91,436	176,444
Scenario 3: 20% Renewable Portfolio Standard (RPS) by 2020 (40% biomass, 55% wind energy, 5% solar PV)	111,879	76,139	188,018
Scenario 4: Fossil Fuels as Usual to 2020 (50% coal and 50% natural gas)	22,711	63,657	86,369
Scenario 5: 20% Gas Intensive by 2020 (100% natural gas)	22,023	61,964	83,987

Table 3: Comparison of the estimated employment created by meeting the equivalent of 20 percent of current U.S. electricity demand via an expansion of fossil- or renewables-based electricity generation.

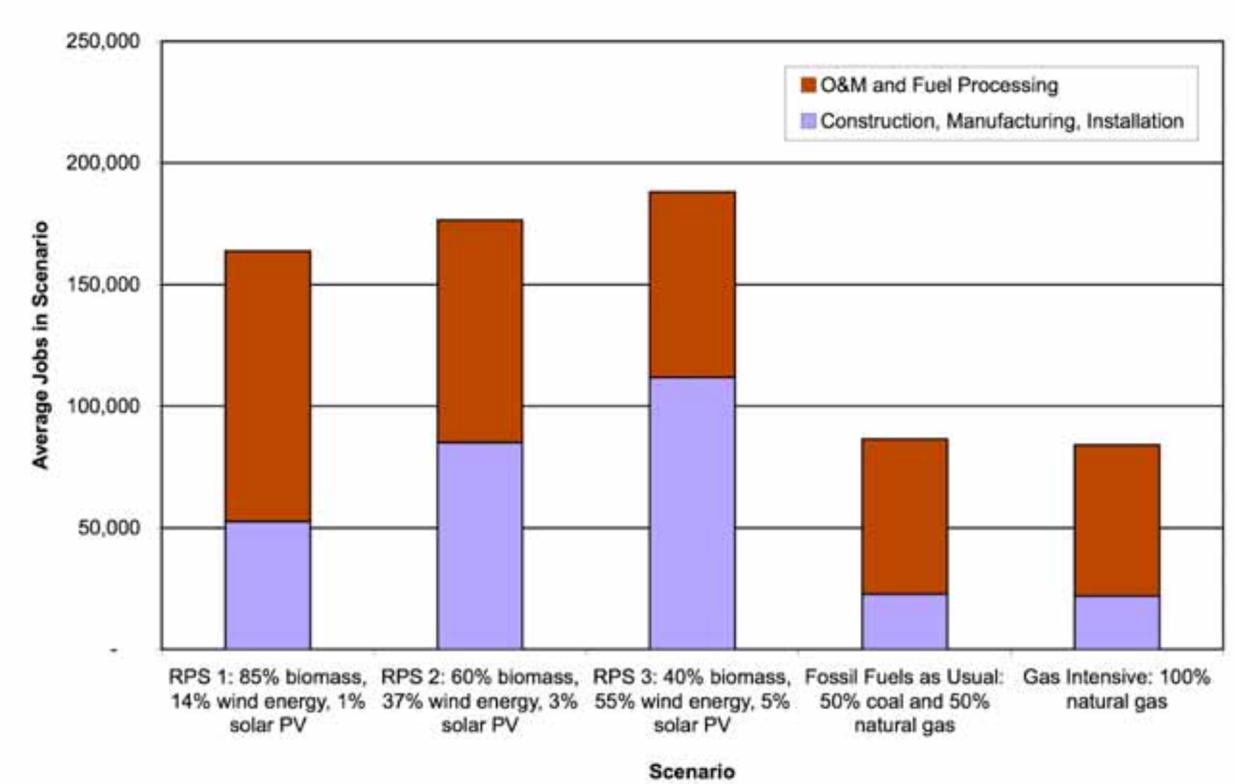

Figure 1: Comparison of average employment from five electricity generation scenarios.

What would large-scale growth in the renewable energy sector mean for those employed in the fossil fuel sector? What are the potential regional employment impacts of large-scale growth in the renewable energy sector?

These two questions are linked, so we address them together. There is little doubt that shifting our energy dependency from fossil fuels to renewables will affect jobs in the fossil fuel sector. The Worldwatch Institute rightly notes that in a shift from fossil fuels to clean energy, while "…the losers are likely to be far outnumbered by the winners, some workers will be hurt in the economic restructuring toward sustainability—primarily those in mining, fossil fuels, and smokestack industries."[5] The "winners" versus "losers" debate also depends critically on the state of the overall energy economy. When demand for energy is rising, as it is now, there is more room for all new suppliers to benefit. A recession, or economic or policy drivers of a shift from one technology to another – such as a shift away from coal that could result from a carbon tax – changes the equation dramatically.

However, it is essential to put the issue of job losses in the fossil fuel industry in perspective:

Overall, the renewable energy industry generates more jobs per MWa than the fossil fuel-based industries (mining, refining and utilities)

Our analysis in the previous section demonstrates that for a variety of feasible scenarios, the renewables industry consistently generates more jobs per MWa in construction, manufacturing and installation, and in O&M and fuel processing, than the fossil fuel industries.

Investment in renewables also generates more jobs per dollar invested than the fossil fuel energy sector. The REPP study[6] calculates that the solar PV industry generates 5.65 person-yrs of employment per million dollars in investment (over 10 years) and the wind energy industry generates 5.7 person-yrs of employment per million dollars in investment (over 10 years). In contrast, every million dollars invested in the coal industry generates only 3.96 person-yrs of employment, over the same time period.

Supporting the renewable energy industry will benefit sectors of the economy and states that currently suffer from high unemployment

The renewable energy industry creates comparatively more jobs in manufacturing than in services and O&M, which will provide a boost to US manufacturing. The results of our model indicate that as we build a clean energy future, jobs in the energy sector are likely to shift from mining and related services to manufacturing, construction and agriculture (if biomass energy forms a large part of the renewables mix). This shift would benefit sectors of the economy suffering from very high unemployment. As Table 4 demonstrates, while unemployment rates in manufacturing and mining are somewhat on par, unemployment rates in construction and agriculture are currently extremely high.

[5] World Watch Study, page 30; study **10** in Appendix 1
[6] Study **6** in Appendix 1

Sector of the Economy	National Annual Average Unemployment Rate (%) 2002	National Annual Average Unemployment Rate (%) 2003
Mining	6.3	6.7
Construction	9.2	9.3
Manufacturing	6.7	6.6
Agriculture	10.1	10.2

Table 4: Unemployment rates in February 2003 and February 2004. Source: *Bureau of Labor Statistics, 2004*[7].

Our model also does not include jobs that may be generated if the US develops a renewable energy industry for export. The study by the Research and Policy Center of Environment California[8] shows that for California alone, a renewable energy industry servicing the export market can generate up to *16 times more employment* than an industry that only manufactures for domestic consumption (see Table 5). Of course, manufacturing for export means producing at an internationally competitive cost, which can be achieved all the easier if the domestic market creates sufficient demand to bring renewables rapidly down the cost curve.

Technology	Construction Employment for International Market	Construction Employment for In-State Market	Operating Employment for In-State Market	Total
Wind	28,900	1,490	18,930	49,320
Geothermal	800	1,230	59,030	61,070
Biomass	na	540	38,070	38,610
Solar PV	20,300	1,120	1,540	23,000
Fuel Cells	28,100	na	na	28,100
Solar Thermal	na	390	550	940
Total	**78,100**	**4,770**	**118,120**	**201,040**

Table 5: Total California employment growth from renewable energy development (person-years). Source. *Environment California, 2003.*

It is not just states suffering from high unemployment in manufacturing that stand to benefit. The Midwest, for instance, is particularly well suited for wind energy development, with the best wind power resources in the United States. According to Greenpeace-USA, North Dakota alone has enough wind power to produce 1.2 million gigawatt-hours of electricity each year[9], which amounts to 32 percent of total U.S. electricity consumption in 2002. The Environmental Law and Policy Center estimates that a renewable energy portfolio standard of 22 percent can generate 36,800 jobs by 2020 in the ten mid-western states, of which over 52 percent will be in the wind energy industry.

[7] Bureau of Labor Statistics website http://www.bls.gov/webapps/legacy/cpsatab11.htm, accessed on 03/19/04.
[8] Study **3** in Appendix 1
[9] Greenpeace USA website. http://www.greenpeaceusa.org/media/publications/losing_racetext.htm. Accessed on 3/3/04.

Extractive industries and utilities provide declining number of jobs, for reasons that have little or nothing to do with environmental regulations

According to the Worldwatch Institute, jobs in extractive industries are on the decline, as mechanization and mergers lead to continuous layoffs. While coal production in the US increased 32 percent between 1980 and 1999, coal-mining employment declined 66 percent, from 242,000 to 83,000 workers. Further, jobs in the coal industry are expected to fall by 36,000 workers between 1995 and 2020, even without any greenhouse gas–reducing policies, such as carbon caps or taxes, in place. In the oil industry, over 40 percent of US oil-refining jobs were lost between 1980 and 1999. Petroleum refining and wholesale distribution account for only 0.3 percent of all US employment in 2000. Further, commodity prices' boom-bust cycles make these industries, and employment in them, very volatile.[10]

Contrary to popular belief, very few of these job losses are caused by environmental regulations. The Worldwatch Institute reports: "A survey of 224 permanent plant closings in 1980–86 by the Oil, Chemical, and Atomic Workers' Union found that just 12 plants listed environmental reasons as a *partial* motive for closure. And surveys conducted by the U.S. Bureau of Labor Statistics from 1987–92 and again from 1995 on show that environment–related reasons for layoffs were of minute significance: 0.14 percent of all layoffs in 1995–97 (the surveys cover layoffs of 50 people or more for a month or longer). All in all, annual layoffs from plants shut down due to environmental regulation have averaged 1,000–3,000 in the United States since the 1970s. Relative to economy-wide layoffs of typically more than 2 million workers each year, this is less than one tenth of 1 percent."[11]

The Worldwatch study also demonstrates that mining and utility companies are responsible for substantial toxic pollution. In 1998, the Environmental Protection Agency revealed that 48 percent of the 7.3 billion pounds of toxic pollutants tracked by its Toxic Release Inventory, are released by mining companies (a category which includes extraction of metals, coal, oil and gas). Another 15 percent of TRI releases were attributed to the utility sector. Although these two sectors were responsible for 63 percent of the toxic releases tracked by the EPA, together they provided only 1.4 million jobs, or 1.3 percent of all private enterprise jobs in the United States in that year.[12]

The fossil fuel industry provides little overall new employment, but generates huge economic externalities through pollution that somebody has to pay to clean up, or has to endure. These externalities become manifest in the loss of productive work days caused by illness due to pollution exposure, costs borne by industry (and eventually consumers) to clean up pollution, or costs borne directly by taxpayers for clean-up.

Although winners will outnumbers the losers, some sectors and regions will clearly be hurt by restructuring the energy industry away from fossil fuels and towards renewables

A net gain to the economy and to employment still means that some people will lose jobs, whatever the state of the fossil fuel industry. It is possible, as already discussed, that people employed in fossil fuel–based industries may not have the required skills for new jobs, and will

[10] Worldwatch Study, pages 33-34; study **10** in Appendix 1
[11] Worldwatch Study, pages 26-27; study **10** in Appendix 1
[12] Worldwatch Study, pages 22-23; study **10** in Appendix 1

need retraining. It is also likely that new jobs may arise in other locations. According to the WWF study[13], even under an optimistic scenario in which all states benefit economically and in terms of net employment by implementing a suite of clean energy policies, some states gain more than others. For example, while California is projected to gain 141,400 new jobs, and Texas 123,400 by 2020, West Virginia is expected to gain only 6,000 new jobs. Controlling for population, this means that Texas will gain almost 70% more jobs than West Virginia by 2020[14].

	Net gain/loss in jobs by 2020
Overall for all sectors of the economy	+ 1,314,000
Coal mining	– 23,900
Oil and gas mining	– 61,400
Oil refining	– 6,300
Electric Utilities	– 35,100
Natural Gas Utilities	– 26,200

Table 6: Net projected losses by sector of the economy in comparison to overall projected net gains.
Source*. Worldwide Fund for Nature. Listed as study* ***5*** *in Appendix 1.*

According to the same study, certain sectors will be net losers, as shown in Table 6.

The fact that there will be some losers does not take away from the case for making a shift in the energy economy towards clean technologies. Perpetuating a region's dependence on volatile and polluting industries with low and steadily declining employment rates is bound to negatively affect that region's development in the long run. This would be especially tragic when we have the option to switch to supporting the growth of a sustainable new sector, which will generate substantial employment.

Of course, negatively impacted people and communities must be adequately compensated. They will need retraining to develop the new skills needed in the clean energy industry. Locally relevant programs will be needed for retooling and retraining, and for attracting new industries. As the Worldwatch study states, "as with any fundamental economic transformation, the transition will require attention. The question facing society today is whether this change can be shaped so that the vast majority of people benefit, and so that social pain during the transition is kept to a minimum."[15]

It is also worth noting that there are energy companies based today largely on fossil-fuels which are well prepared to make a substantial shift in their energy business. Both British Petroleum (BP) and Shell, for instance, own two of the world's three largest solar energy companies. In 2002, BP Solar supplied 14 percent of global PV shipments, and Shell Solar 10 percent.

The United States has a lot of catching up to do. For instance, in 2003, total US production of solar PV modules amounted to 121 MWp (21 percent of global solar PV production). This was less than half of Japan's 251 MWp (45 percent of global production) and also less than Europe's 135 MWp (24 percent of global production) that same year[16]. Of the top ten solar PV module

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[13] Study **5** in Appendix 1
[14] Assuming that the ratio of population distribution between states remains the same as today.
[15] Worldwatch Study, pages 9-10; study **10** in Appendix 1
[16] *PV News*, 22(3), March 2003

producers in 2002, only one was an American company (Astropower), although some of the others manufacture (and thus generate jobs) in the United States (for example, BP Solar and Shell Solar both have manufacturing plants in the US).

What policy measures would maximize the net positive economic and employment benefits that the renewable energy industry offers?

There are a suite of policy instruments that can be used to promote renewable energy technologies. These range from financial instruments like tax credits and bond measures to renewable portfolio standards, and support for R&D. Since the focus of this report is the employment dimension of renewables, we will not provide here a complete run-through of policy options. This has been done elsewhere[17], and a set of recommended highest-priority policies is listed in brief in Appendix 3. This section focuses instead on policy requirements to maximize employment benefits while minimizing the negative impacts on people employed in the fossil fuel energy sector. We identify two key areas of intervention, discussed below.

Placing support for renewables in a broader context of support for clean energy measures, including energy efficiency and sustainable transportation will greatly augment economic and employment benefits

Renewable energy, energy efficiency and sustainable transportation are complementary sectors that support and enhance each other. For example, using a solar PV system in the most economic way possible requires that all the appliances being used are energy efficient. Measures that make it easy for an electricity customer to install a solar PV system and retrofit his or her building to be energy efficient will enhance the likelihood of that customer doing both. Consider the market for biomass energy fuels: bio-fuels like ethanol or bio-diesel require that bio-fuel powered cars are easily available, supported by an infrastructure of fuelling stations. In other words, the growth of a particular segment of the clean energy family – be it renewable energy, energy efficiency or sustainable transportation – is often partly dependent on growth in other parts of the energy industry.

This is not to say that a certain sector cannot grow by itself (for instance, a renewable portfolio standard is a good idea irrespective of the presence of other complementary policies). However, it is likely that the renewables sector, and jobs in it, will grow much more quickly if complementary policy measures are in place. This is partly why some of the studies reviewed model an array of policies in all clean energy sectors together. For example, the Apollo Jobs study[18] models a comprehensive scenario of policy and program support in which federal investment of $300 billion is made over 10 years in four categories: increasing energy diversity, investing in industries of the future, promoting high performance buildings, and rebuilding public infrastructure. In this scenario, supporting renewables alone is projected to create 459,189 jobs, while the total investment is projected to yield over 3.3 million jobs.

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[17] Testimony of Daniel M. Kammen for the U. S. Senate Commerce, Science and Transportation Committee, "Technology and Policy Options to Address Climate Change". July 10, 2001. Senator John Kerry (D-MA), Chair. Testimony adapted and published in journal form as: Herzog, A. V., Lipman, T., Edwards, J. and Kammen, D. M. (2001) "Renewable Energy: A Viable Choice", *Environment*, 43 (10), 8–20. Note that most of the studies reviewed also provide detailed lists of policy prescriptions for spurring the development of the clean energy sector.

[18] Study **1** in Appendix 1

Programs are needed to retool and retrain those who stand to lose their jobs in the fossil fuel industry

As discussed above, workers who lose their jobs in the fossil fuel industry should have the opportunity to retrain themselves for employment in the clean energy industry. Programs could include:

- Free or low-cost training and certification courses in installation and maintenance of renewable energy systems
- Financial/tax incentives for renewable energy companies which absorb and train unemployed workers
- Support for community colleges and schools that offer training and certification programs in renewables and energy efficiency

Conclusion – Clean Energy for a Sustainable and Prosperous Future

Transitioning from a fossil fuel–based economy to a renewably powered one will spur economic growth and provide considerable employment. A review of 13 studies and our own analysis concur with this conclusion. The national and international security implications of spurring employment through local, sustainable energy generation are compelling. The United States needs to regain its international position as a technology leader, and the technologies of the future are in clean energy. The time is ripe to move beyond studies to action.

Author Biographies

Matthias Fripp is a PhD student in the Energy and Resources Group (ERG) at UC Berkeley. He is studying the integration of renewables into the US electric grid. Matthias holds an M.S. from ERG and a B.A. in environmental studies from Lewis & Clark College in Portland, Oregon. Before coming to Berkeley, he worked for Trexler and Associates, Inc. (a consulting firm specializing in in climate-change mitigation), and was a researcher at the Renewable Northwest Project, both located in Portland.

Daniel M. Kammen directs the Renewable and Appropriate Energy Laboratory (RAEL) at the University of California, Berkeley, where he a professor in the Energy and Resources Group, the Goldman School of Public Policy, and the Department of Nuclear Engineering. Kammen's research is focused on solar, wind, and biomass energy supplies, clean water for developing nations, and on the production and use of hydrogen and fuel cells for stationary power production and for vehicles. Kammen is involved in national and international energy policy analysis and debates, which includes issues of energy resources for both developed and developing nations, and on global and regional climate change. He has testified in front of House and Senate Committees, served as a technical reviewer for the Global Environment Facility, and is a permanent member of the African Academy of Sciences. He is the author of over 150 research papers and reports, and six books, including *Should We Risk It?* (Princeton University Press, 1999). Copies of Professor Kammen's publications, and information on the activities of the Renewable and Appropriate Energy Laboratory can be accessed on the website: **http://socrates.berkeley.edu/~rael/.**

Kamal Kapadia is a PhD student in the Energy and Resources Group (ERG) at UC Berkeley. Her research examines renewable energy technologies use in developing countries. Kamal holds an M.A. from ERG and an M.S. in Environmental Change and Management from the University of Oxford, UK. Before coming to Berkeley, she worked for solar energy companies in the UK, Sri Lanka and India.

APPENDIX 1: SUMMARY OF STUDIES REVIEWED

Number	Year	Author	Study	Method	Scenarios used
1	2004	The Institute for America's Future, The Center On Wisconsin Strategy and The Perryman Group, Waco TX.	The Apollo Jobs Report: For Good Jobs & Energy Independence New Energy for America	Presents scenarios based on a model in which $300 Billion of federal investment is made over 10 years in 4 categories: increasing energy diversity, investing in industries of the future, promoting high performance buildings, rebuilding public infrastructure.	$300 Billion of recommended federal investment includes: 1. $30 Billion support for strengthening the renewables market to get 15% renewables in electricity mix by 2015, and 20% by 2020. 2. $6 Billion for bio-energy resource development 3. $6.5 Billion for hydrogen fuel cell R&D and deployment.
2	2003	Greenpeace/European Wind Energy Association	Wind Force 12. A Blueprint to Achieve 12% of the World's Electricity from Wind Power by 2020.	Uses data from comprehensive study on wind and employment by the Danish Wind Turbine Manufacturers Association (DWTMA) in 1996, updated in 1998. Methodology used by the DWTMA is to break down the manufacturing activities into different sectors – metalwork, electronics, etc and add together individual employment contributions. Results cover three areas – direct and indirect employment from wind turbine manufacture, the direct and indirect employment effects of installing wind turbines, and the global employment effects of the Danish industry's exports business. To allow for greater efficiencies in design, manufacture and installation – resulting in a reduction in employment labour consumption is assumed to follow total value of wind energy installation, a decreasing value over time.	Calculates the employment effect of the 12% global wind energy scenario. For OECD-North America, this means 310,000 MW of wind installed by 2020, for USA alone, 250,000MW.
3	2003	Environment California Research and Policy Center (Brad Heavner and Bernadette Del Chiaro)	Renewable Energy and Jobs. Employment Impacts of Developing Markets for Renewables in California	Uses numbers from above study, based on which authors calculate jobs in California from foreign RET markets, assuming California has 5% market share of geothermal, and 10 % of other technologies.	20% renewables in electricity mix by 2010 in California, which involves addition of 5,900MW renewables, where California has 30% of construction/manufacturing jobs to meet in-state RPS, and 90% of O&M jobs for all technologies. In addition, California also has 10% of manufacturing/construction jobs for foreign markets for renewables (all except geothermal, where California construction job share is 5%)
4	2002	CALPIRG (Brad Heavner and Susannah Churchill)	Renewables Work. Job Growth from Renewable Energy Development in California	Study focussed on California only. Reviews several other studies. Study also collected primary data from renewables industry and natural gas utilities on direct and indirect jobs, and reported results as employment from construction and eployment from operation and maintenance, by technology.	20% renewables in electricity mix by 2010 in California, which involves addition of 5,900MW renewables in ratio of 11% wind, 7% geothermal, 0.2% solar PV, 1% solar thermal, 1% landfill gas.
5	2001	World Wide Fund for Nature (Study conducted by Tellus Institute and MRG Associates)	Clean Energy: Jobs for America's Future	Study models employment, macroeconomic, energy and environmental impacts of an entire range of clean energy policies called "Climate Protectio Scenario". Includes variety of policies measures in building and industry sector, electric sector, transport sector. Uses I-O Model (IMPLAN) tracing linkages in the economy. Policies were compared to base case as given in IEA Annual Energy Outlook 2001. Since macroeconomic impacts are only reported by sector of economy (e.g. agriculture, finance etc), it is not possible to tease out employment impact of renewables alone from the study itself.	For renewables - a US-wide RPS of 15% renewables in the electricity mix by 2020. Total investment needed not specified, however, net impact of all policies in the model predicted to have net positive impact on GDP of $(1998) 23,220 Million by 2010 and $ (1998) 43,860 Million by 2020.
6	2001	Renewable Energy Policy Project (co-authored by Virender Singh of REPP and Jeffrey Fehrs of BBC Research and Consulting)	The Work that Goes into Renewable Energy	Study calculates jobs in person-yrs/MW and person-yrs/$ invested. Uses a simple model, does not take into account multiplier effects as an I-O model would. Authors collected primary employment data from companies in the solar PV, wind energy and coal sectors, and used project scenario numbers for biomass energy. Study takes in account jobs in manufacture, transport and delivery, construction and installation, and O&M.	None

APPENDIX 1: SUMMARY OF STUDIES REVIEWED

Number	Year	Author	Study	Method	Scenarios used
7	2001	Dan Kammen and Kamal Kapadia, Energy and Resources Group, University of California, Berkeley	Jobs from Renewables, Study for Kerry/Kennedy committee	Analysis based on combining industry data with median values of economic models produced by others.	Scenario of 10% US-wide RPS, where 5% of total electricity in 2010 would come from solar PV, 60% from biomass energy and 35% from wind energy.
8	2001	Greenpeace	2 Million Jobs by 2020. Solar Generation. Solar Electricity for over 1 billion people and 2 million jobs by 2020.	Based on employment information provided by the industry, jobs for each world region have been calculated for scenario of 207GWp of installed PV by 2020 . It is ssumed that between 2000 and 2010, 20 jobs are created per MWduring manufacture, decreasing to 10 Jobs per MW between 2010 and 2020. About 30 jobs generated per MW during installation, retailing and providing other local services between 2000 and 2010, going down to 26 jobs per MW between 2010 and 2020. For maintenance, it is assumed that after accunting for economies of scale and other efficiency gains, 1 job will be created per installed MW. Since developing world markets will play a more significant role beyond 2010, proportion of maintenance work is assumed to steadily increase up to 2 jobs per MW by 2020.	By 2020, the goal is to install 207GWp of solar PV globally. Average annual growth rate in PV markets worldwide up to 2009 is projected to be 27% and then rising to 34% between 2010 and 2020. Although initial growth is expected to be fastest in the grid-connected sector, by 2010 this will be replaced by the emerging off-grid rural sector.
9	2001	Environmental Law & Policy Center (study done by the Regional Economics Applications Laboratory: Geoffrey Hewings and Moshe Yanai)	Job Jolt" The Economic Impact of *Repowering the Midwest. A Clean Energy Development Plan for the Heartland*	Regional econometric input-output models developed by REAL to forecast local impacts of changing economic conditions and policies. Using primarily U.S. Census data, REAL's dynamic models track employment, income and output data across 53 industrial sectors, factoring in 13 demand variables (consumption, investment, government expenditures, etc.) and eight demographic variables (age, sex, migration, etc).	Clean Energy Development Plan for 10 mid-western states as outlined in related report *Repowering the Midwest. A Clean Energy Development Plan for the Heartland* . Policies include portfolio of policies in energy efficiency, and an 8% RPS by 2010, 22% by 2020
10	2000	Michael Renner, Worldwatch Institute	Working for the Environment: A Growing Source of Jobs (Worldwatch Paper 152)	Discussion paper on employment impacts of environmental policies and programs. Includes discussion of impacts of environmental programs on employment in the fossil fuel industry, and a section on employment benefits of the renewable energy industry.	NA
11	1999	European Wind Energy Association/European Commission Directorate-General for Energy	Wind Energy: The Facts	Numbers based on 2 prior studies/surveys carried out to determine exisiting employment in wind industry in Europe - Danish Wind Turbine Manufacturers Association and Danish Counties and Municipalities Research Institute (Society Value of Wind Power).	100,000MW of wind energy in the European Comission member countries NOTE: AWEA Wind Energy Fact Sheet (Wind Energy and Economic Development: Building Sustainable Jobs and Communities) refers to EWEA employment figures.
12	1999	European Commission/ALTENER Programme DG for Energy and Transport	Meeting the Targets and Putting Renewables to Work	Uses SAFIRE Energy Model to predict market penetration for RETs and displacement of other technologies for different scenarios. Then RIOT (renewables enhanced input-output tabes) I-O Model is used to calculate employment impact. Model is based on calculation of production funcions that represents the value of inputs (including employment) from different sectors of economy needed to produce a unit of energy from different technologies. Models predict direct and indirect jobs and jobs from agriculture, minus potential losses in conventional energy sector and support mechanisms leading to lower spending elsewhere in the economy.	2 scenarios are modelled - current EU policies, or "CP" scenario, where renewables make up 20.4% of gross European electricity consumption by 2020, and advanced renewable strategy or "ARS" scenario, where renewables make up 27.6% of gross electricity consumption by 2020.
13	1998	Skip Laitner, Stephen Bernow, John DeCicco	"Employment and other macroeconomic benefits of an innovation-led climate strategy for the United States." *Energy Policy* 26, 5: 425-432.	Study used IMPLAN ("Impact analysis for Planning"), I-O model to evaluate impact of "the Innovation Path" scenario Macroeconomic impact calculated for all major sectors of economy. Not possible to tease out impact of renewables only from paper.	"The Innovation Path" scenario, includes policies in residential, commercial, industrial, transportation, and electricity generation secors, to reduce carbon intensity of the US economy by 25.5% by 2010. Policies include variety of energy efficiency measures, renewables development, and development and deployment of near-commerical technologies.

APPENDIX 2: ASSUMPTIONS AND SOURCES FOR OUR MODEL AND SCENARIOS

The results in our scenarios are only indicative. Comparing jobs/MWa figures from different sources is very difficult, since each study and method draws boundaries at different points in terms of the direct and indirect jobs to include.

Sources and Assumptions for Employment Figures in Table 2 (page 10)

1. For solar PV, wind energy, biomass energy and coal, we have used data from the REPP Report (study 6 in Appendix 1), the Greenpeace Solar Energy Report (study 8 in Appendix 1), and the Greenpeace/EWEA Wind Energy Report (study 11 in Appendix 1), as specified in the table.
2. For wind energy, as the Greenpeace/EWEA study has not specified employment from O&M, we have used the employment figure from the REPP study for both wind energy cases cited.
3. For biomass energy, the high-estimate figures for jobs in O&M and fuel extraction and processing, are based on the upper-end of estimates provided for switchgrass cultivation, and the low estimates are based on the low-end of estimates provided for energy from urban wood waste. As no numbers were supplied in the REPP Report for the manufacture, construction and installation of the energy facility per se, we have assumed that the energy facility would be similar to a coal-fired power plant, and used employment figures for "making coal plant components and for on-site activities, not including O&M" as provided in the REPP report in Appendix B (page 25).
4. For natural gas-based electricity, we have used three different sources:
    a. Manufacturing and construction of the power plant facility is assumed to be the same as for a coal-powered facility, as given in the REPP study. The CALPIRG Study (no. 4 in Appendix 1) also provides employment figures for construction of natural gas facilities, but not for manufacturing the components.
    b. O&M employment figures for the natural gas industry have been taken from the CALPIRG study.
    c. Employment from natural gas extraction and distribution is calculated from data from the Bureau of Labor Statistics and the Energy Information Agency (EIA). The Bureau of Labor Statistics reports 112,510 jobs in 2002 in Natural Gas Distribution and 119,130 jobs in 2002 in Oil and Gas Extraction (http://www.bls.gov). In 2002, natural gas provided 61 percent of the total energy delivered by oil and gas extracted in the U.S., so we assigned 61 percent of the oil and gas extraction jobs (72,900 jobs) to natural gas. Taken with the gas distribution jobs, this yields a total of 185,400 people employed in gas extraction and distribution in the U.S. in 2002. In the same year, 24.7 percent of natural gas consumed in the U.S. was used for electricity production, so we estimate that 45,900 people were employed in the U.S. to extract and deliver natural gas for the electricity sector. The EIA also reports that 685,800 GWh of electricity were produced from natural gas in the U.S. in 2002, so we calculate that each GWh of electricity produced from natural gas requires 0.067 person-years of employment in gas extraction and distribution. (*Source:* Tables 6.5 and 8.2a of the EIA *Annual Energy Review 2002*, available on-line at http://www.eia.doe.gov/emeu/aer/)
5. We have not included any numbers for nuclear energy, as we have been unable to locate data sources.

APPENDIX 2: ASSUMPTIONS AND SOURCES FOR OUR MODEL AND SCENARIOS

Sources and Assumptions for Scenarios 1–5 (page 11)

1. All electricity generation figures are taken from the EIA *Annual Energy Review 2002*, available on-line at http://www.eia.doe.gov/emeu/aer/.
2. Total electricity generated in the US in 2002 was 3,858,452 GWh. We assume this figure stays constant till 2020, as efficiency gains accompanying a large-scale renewable energy deployment offset the current rate of increase in electricity demand of 2–3 percent a year. This assumption will almost certainly prove to be incorrect, but it does provide a consistent way to compare policies, and our comparative findings will continue to hold even with different assumptions about growth of the electricity supply.
3. We have not included hydro-power as a renewable energy source, as the environmental impact of large hydro facilities is a point of considerable contention. Further, we do not anticipate any substantial increase in hydropower capacity in the country, nor is it a large employer within the energy industry (as there is no ongoing manufacturing, nor fuel extraction involved).
4. Our scenarios are scaled around the current existing mix of renewables in electricity, in which 85% is from biomass energy (wood and waste fuel), 14% from wind energy, and 1% from solar PV.
5. In cases where we have low and high estimates for jobs (solar PV, wind energy and biomass energy), we have averaged the two estimates.

APPENDIX 3: POLICY RECOMMENDATIONS FOR ACCELERATING THE DEPLOYMENT OF RENEWABLES

Rapidly but efficiently expanding the renewable energy sector is the most important single step to achieve energy independence, job growth, and meaningful environmental protection. To achieve this goal, markets must be opened for new, clean renewable energy and energy efficiency innovations. In our view, the Renewable Portfolio Standard provides the best near-term mechanism and framework for growth of the solar, wind, biomass, and geothermal generating sectors. A variety of other mechanisms are needed to spur innovation and implementation of clean energy options, but the RPS provides the most natural framework.
We find that a 20% RPS – either as a federal standard or as a federally-supported patchwork of state measures – by 2020 is not only achievable, but would provide a major economic boom to the U.S. economy through job creation and through the export markets we could then address.

By 2050 our energy economy could be driven by over 40 percent renewable energy sources, with higher levels quite plausibly – technologically, economically, and environmentally possible.

The critical move is the first step. A suite of recommended policies would include the following measures, most of which were first proposed by Professor Kammen at the July 10, 2001 Senate Committee on Science, Commerce and Transportation chaired by Senator Kerry.[19]

[19] Kammen, D. M. (2001) Testimony for the Hearing on 'Technology and Policy Options for Climate Change' for the U. S. Senate Committee on Commerce, Science, and Transportation, July 10 (United States Senate: Senate Committee on Commerce, Science, and Transportation). URL http://www.senate.gov/~commerce/

Appeared in revised form as: D. M. Herzog, A. V., Lipman, T., Edwards, J. and Kammen, D. M. (2001) "Renewable Energy: A Viable Choice", Environment, 43 (10), 8 – 20.

APPENDIX 3: POLICY RECOMMENDATIONS FOR ACCELERATING THE DEPLOYMENT OF RENEWABLES

Energy Policy Recommendations

- **Increase Federal R&D Funding for Renewable Energy and Energy Efficiency Technologies**

Federal investment in renewable energy and energy efficient technologies has been sparse and erratic[20], with each year producing an appropriations battle that is often lost. A combination of a federal program for steadily increasing funding and active political leadership would transform the clean energy sector from a good idea to a pillar of the new economy.

- **Provide Tax Incentives for Companies the Develop and Use Renewable Energy and Energy Efficiency Technologies**

Support for the production and further development of renewable fuels, all found domestically, would have a greater long-term effect on the energy system than any expansion of fossil-fuel capacity, with major health and environmental benefits as an added bonus. We should extend the existing production tax credits (PTC) for electricity generated from wind power and closed loop biomass for five years. Also, this production credit should be expanded to include electricity produced by open loop biomass (i.e., agricultural and forestry residues but excluding municipal solid waste), geothermal energy, and landfill gas. The same credit should be provided to closed loop biomass co-fired with coal, and a smaller credit (one cent per kWh) should be provided for electricity from open-loop biomass co-fired with coal. We support a minimum of a 15 percent investment tax credit for residential solar electric and water heating systems. In addition, we recommend a 30 percent investment tax credit for small (75 kW and below) wind power systems.

- **Improved Federal Standards for Vehicle Fuel Economy and Increased Incentives for High Fuel Economy Vehicles**

We need to first remove the separate fuel economy standards for cars and light trucks (i.e., close the light truck 'loophole' as proposed in 2001 by Senators Feinstein and Snowe and by Rep. Olver). We then believe that a 40 mpg combined car and light truck fuel economy standard could be accomplished in the 2008 to 2012 timeframe with negligible net cost. We support tax credits of up to $5,000 for hybrid electric vehicles, up to $6,000 for battery electric vehicles, and $8,000 for fuel cell vehicles, and an incentive scheme for energy-use performance that rewards both fuel savings and lower emissions.

- **A Federal Renewable Portfolio Standard (RPS) to Help Build Renewable Energy Markets**

We support a 20 percent RPS by 2020. A number of studies indicate that this would result in renewable energy development in every region of the country with most coming from wind, biomass, and geothermal sources. A clear and properly constructed federal standard is needed to set a clear target for industry research, development, and market growth. We recommend a renewable energy component of 10 percent in 2010 and 20 percent by 2020 that would include wind, biomass, geothermal, solar, and landfill gas.

[20] Margolis, R. and Kammen, D. M. (1999) "Underinvestment: The energy technology and R&D policy challenge", *Science*, **285**, 690 - 692

APPENDIX 3: POLICY RECOMMENDATIONS FOR ACCELERATING THE DEPLOYMENT OF RENEWABLES

- **Federal Standards and Credits to Support Distributed Small-Scale Energy Generation and Cogeneration (CHP)**

Small scale distributed electricity generation has several advantages over traditional central-station utility service, including reducing line losses, deferring the need for new transmission capacity and substation upgrades, providing voltage support, and reducing the demand for spinning reserve capacity. In addition, locating generating equipment close to the end use allows waste heat to be utilized to meet heating and hot water demands, significantly boosting overall system efficiency. We support at least a 10 percent investment tax credit and seven-year depreciation period for renewable energy systems or combined heat and power systems with an overall efficiency of at least 60-70 percent depending on system size.

- **Enact New and Strengthen Current Efficiency Standards for Buildings, Equipment, and Appliances**

Significant advances in heating and cooling systems, motor and appliance efficiency have been made in recent years, but more improvements are technologically possible and economically feasible. A clear federal statement of desired improvements in system efficiency is needed to remove uncertainty and reduce the economic costs of implementing these changes. Under such a federal mandate, efficiency standards for equipment and appliances could be steadily increased, helping to expand the market share of existing high efficiency systems.

- **Institute a National Public Benefits Fund**

We recommend a public benefits fund financed through a $0.002/kWh charge on all electricity sales. Such a fund could match state funds to assist in continuing or expanding energy efficiency, low-income services, the deployment of renewables, research and development, as well as public purpose programs the costs of which have traditionally been incorporated into electricity rates by regulated utilities.

- **Investigate and Work Towards a Carbon Tax**

A diverse range of analyses – environmental, economic, and from an energy policy perspective – all support the notion that a carbon tax provides one of, if not the, most effective means to efficiently and cost-effectively safeguard the environment while encouraging economic growth. We strongly support the notion of a carbon tax, and would welcome the public discussion and exchange that high-level recognition of this vehicle would engender. A carbon tax could be gradually implemented, beginning at a token level, and could be managed to work effectively between mobile and stationary sources of emission

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