
The jobs impact of GHG reduction strategies in the USA

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Abstract: This paper estimates the economic and jobs impact of the USA displacing 1.2 billion tons of carbon emissions annually by 2030 using energy efficiency and renewable energy. We assess the technologies deployed, their costs, and the necessary time frames. We then estimate the job impacts of the policy and find that it will generate more than 4.5 million net jobs. We disaggregate the jobs created by industry, occupation, skill, and salary, and discuss the policy implications of these findings. Our major conclusion is that climate mitigation initiatives can be a major net job creator for the USA.

Keywords: climate change mitigation; global warming jobs; GHG job impact; energy efficiency and renewable energy jobs; USA.

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Robert M. Wendling has 30 years experience in energy market analyses, energy policy, and research. He created the Commerce Department's Econometric National-Regional Impact Evaluation System and is the former Director of Commerce's Economic Statistics Office, *STAT-USA*. He has served as a Senior Economist at the Department of Energy and as a Policy Advisor to the Assistant Secretary. He received his BA in Economics from Indiana University and MA in Economics from George Washington University.

1 Introduction

The American Solar Energy Society (2007) published the report ‘Tackling Climate Change in the US: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030’ (TCC) which illustrated how energy efficiency (EE) and renewable energy (RE) technologies can provide the emissions reductions required to address global warming. It analysed numerous EE applications and assessed six RE technologies: concentrating solar power, photovoltaics, wind power, biomass, biofuels, and geothermal power. The findings indicated that these technologies could displace 1.2 billion tons of US carbon emissions annually by 2030 – the magnitude of reduction that may be necessary to mitigate climate change. However, the report did not estimate the jobs impacts of the TCC initiatives, and the jobs issue has become increasingly important and contentious in the climate change mitigation debate. Our objectives here are to estimate the jobs impacts through 2030 of the initiatives detailed in TCC and determine the net jobs impact on the USA economy.

2 Methodology

2.1 Achieving climate change mitigation goals

Addressing global warming implies limiting carbon dioxide (CO₂) levels in the atmosphere to 450 to 500 ppm, and industrialised nations may have to reduce CO₂ emissions 60% to 80% below current levels by mid-century (Al-Amin and Filho, 2012). Figure 1 shows the US emissions reductions that would be required by 2030 to achieve this goal. Accounting for expected population and economic growth and associated increases in carbon emissions indicates that in 2030 the USA needs to displace between 1,100 and 1,300 million metric tons of carbon annually.

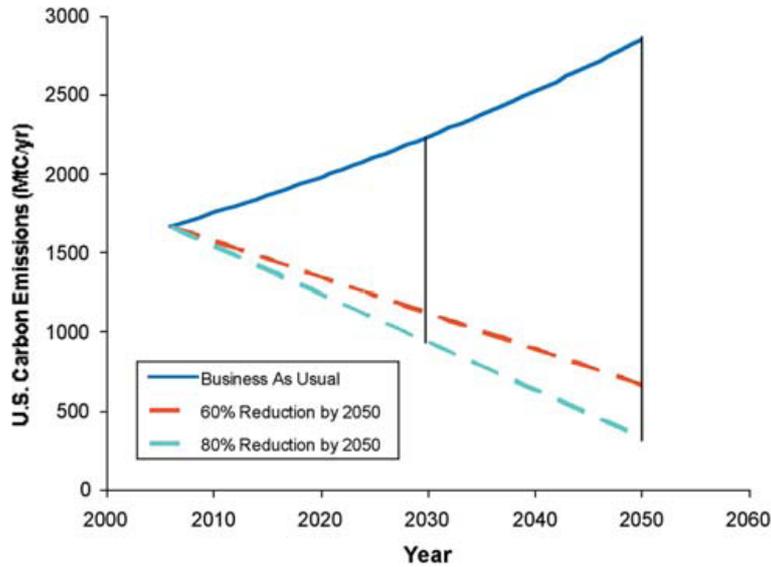
TCC assessed EE&RE technologies to determine the potential carbon reduction for each, discussed current and expected future costs, and developed supply and carbon-reduction curves for 2015 and 2030. Table 1 and Figure 2 summarise the potential carbon reduction contributions from the various areas, and Figure 3 shows the contributions through 2030. Approximately 57% of the total carbon reduction contribution is from EE and about 43% is from RE. EE measures can allow US carbon emissions to remain about level through 2030, whereas the renewable technologies can provide large reductions in carbon emissions below current levels.

Table 1 Potential carbon reductions

<i>Application</i>	<i>Potential carbon reductions (MtC/yr.)</i>
Energy efficiency	688
Concentrating solar power	63
Photovoltaics	63
Wind	181
Biofuels	58
Biomass	75
Geothermal	83

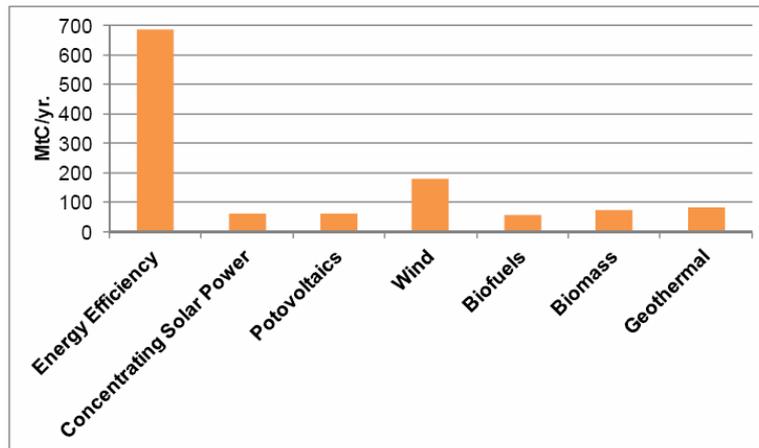
Source: American Solar Energy Society (2007)

Figure 1 US fossil fuel carbon reductions required by 2030 (see online version for colours)



Source: American Solar Energy Society (2007)

Figure 2 Potential carbon reductions by technology (see online version for colours)

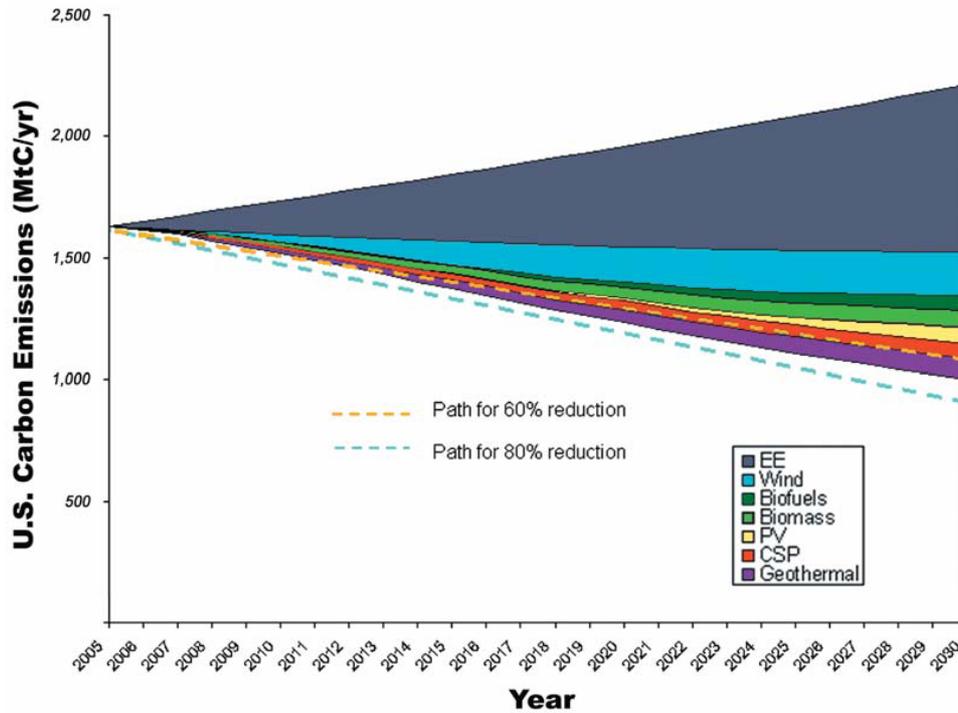


Source: American Solar Energy Society (2007)

2.2 The MISI model

The economic and employment effects of the TCC initiative were estimated using the Management Information Services, Inc. model, data base, and information system (Bezdek et al., 2010). A simplified version of the MISI model as applied in this study is shown in Figure 4.

Figure 3 Potential carbon reductions required in 2030 (see online version for colours)



Source: American Solar Energy Society (2007)

The first step in the MISI model involves estimation of the direct requirements of the TCC initiative from every supporting industry in the economy. For example, construction of a photovoltaics power system will require a wide range of hardware and services from many industries, whereas production of electric and hybrid vehicles will generate requirements from a very different configuration of industries. Production of a photovoltaics power system will generate large direct requirements in the electrical equipment and components, computer and electronic products, non-metallic minerals, and related industries, whereas production of electric and hybrid vehicles will generate large direct requirements in the motor vehicle and parts, plastics and rubber products, primary metals, fabricated metal products, and related industries.

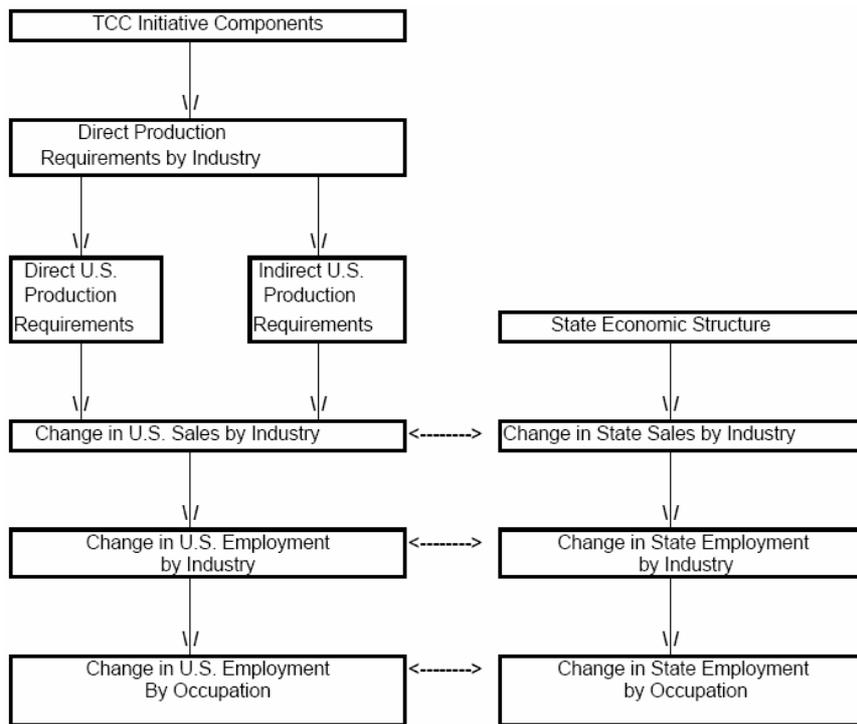
The MISI model translates expenditures for the specified TCC initiative component into per unit output requirements from every supporting industry in the economy. In general, this is determined by four major factors:

- 1 the specific TCC initiative component
- 2 the distribution of expenditures among industries
- 3 the specific expenditure/technology configuration
- 4 the direct industry requirements structure.

While the MISI model contains 490 and industries, in the work conducted here a 70-order industry scheme was used.

Second, the direct output requirements of every supporting industry affected as a result of the TCC initiative are estimated, and they reflect the production and technology requirements implied by the initiative. These direct requirements show, proportionately, how much an industry must purchase from every other industry to produce one unit of output.

Figure 4 Use of the MISI model to estimate the economic, employment, and occupational impacts of the TCC initiative



Direct requirements, however, give rise to subsequent rounds of indirect requirements. For example, electric and hybrid vehicles will require steel, and steel mills require electricity to produce steel. But an electric utility requires turbines from a factory to produce electricity. The factory requires steel from steel mills to produce turbines, and the steel mill requires more electricity, and so on.

The latter are the indirect requirements. The sum of the direct plus the indirect requirements represents the total output requirements from an industry necessary to produce one unit of output for the TCC initiative. Economic input-output techniques allow the computation of the direct as well as the indirect production requirements, and these total requirements are represented by the ‘inverse’ equations in the model. The ratio of the total requirements to the direct requirements is called the input-output multiplier.

Thus, in the third step in the modelling sequence the direct industry output requirements are converted into total output requirements from every industry by means of the input-output inverse equations. These equations show not only the direct requirements, but also the second, third, fourth, nth round indirect industry and service sector requirements resulting from the EE&RE expenditures.

Next, the total output requirements from each industry are used to compute sales volumes, value added (including profits and taxes) for each industry. Then, using data on manhours, labour requirements, and productivity, employment requirements within each industry are estimated. This allows computation of the total number of jobs created within each industry.

The next step requires the conversion of total employment requirements by industry into job requirements for specific occupations and skills. To accomplish this, MISI utilises data on the occupational composition of the labour force within each industry and estimates job requirements for 800 occupations encompassing the entire US labour force. This permits estimation of the impact of TCC expenditures on jobs for specific occupations and on skills, education, and training requirements.

Utilising the modelling approach outlined above, the MISI model allows estimation of the effects on employment, personal income, corporate sales and profits, and government tax revenues in the USA and in each state. Estimates can then be developed for detailed industries and occupations. The methodology employed is state-of-the-art and credible, and has been used by MISI over past three decades in many studies of energy and environmental projects, economic initiatives, proposed legislation, government programmes, etc. (Bezdek et al., 2010; Management Information Services, Inc., 2009).

The advantages of this type of I-O analysis include its flexibility, ease of use, and transparency; however, there are limitations and caveats associated with the input-output modelling approach that should be noted. First, I-O coefficients are based on a rather simple concept of production, and assume that no time elapses between circulating inputs and outputs. Second, a major limitation of the I-O model is its lack of supply side constraints, and the implications of this are frequently overlooked in economic impact analysis. Third, I-O assumes that there are no constraints on resources and that supply is infinite and perfectly elastic. Fourth, the I-O model does not accommodate energy and environmental externalities. Fifth, I-O gives a static vision of the economy in the benchmark year, and this makes forecasting and some other types of analyses difficult. Finally, I-O is based on fixed production function, and does not allow for substitution of the inputs.

2.3 Application to the TCC initiative

The TCC study analysed how EE&RE technologies can provide the carbon reductions through 2030 needed to address global warming (American Solar Energy Society, 2007), and the costs for these technologies were estimated (Kutscher, 2008). The annualised costs were estimated to range from breakeven for wind up to \$9.2 billion for cellulosic ethanol biofuels. In total, the RE will cost less than \$30 billion per year over the period, while the EE technologies deployed are estimated to save almost \$108 billion annually and deployment of these technologies to address climate change is estimated to result in a net savings of over \$82 billion.

These deployment costs and energy savings will help grow EE&RE industries and lead to job creation. However, in this net analysis, we are also concerned about the job losses that will occur due to replacement of existing energy sources. Taking the detailed estimated annual alternate energy and EE costs and the detailed annual net cost estimates for each conventional technology, annual net costs were derived for. While the

net EE savings will decline from an estimated \$128 billion in 2010 to just over \$16 billion in 2030, the net costs to deploy photovoltaics will increase from \$4 billion in 2010 to over \$15 billion by 2030. The TCC cost study also found that both the wind and biofuels technologies will become cost-competitive over the period as technology costs decline.

These detailed annual costs were used to estimate the size and growth of the domestic alternate energy technology 'industries' and the decrease in the conventional energy supplying industry. For 2020 and 2030, the two estimates of the economic activity in the industry attributable to the TCC initiative (alternate renewable sources and conventional sources) were converted to GDP final demand purchases by industry and applied to the MISI input-output total requirements matrix. Because of the consistent annual stream of energy savings from the EE technology source, the GDP final demand purchases by industry included not only the economic activity in the EE industry, but also the dollar savings to the economy. Utilising the two GDP final demand vectors, the MISI model estimates the direct and indirect economic impacts on the economy by industry, jobs by industry, and jobs by occupation. The gross economic output impacts from the MISI model were netted out by subtracting the conventional industry impacts from the alternate energy industry impacts. The net industry dollar impacts by industry for each technology in 2020 and 2030 were then used to estimate the net number of jobs and the occupational profiles of jobs gained and lost. The jobs concept used here is a full-time-equivalent (FTE) job, which is defined as 2,080 hours worked in a year's time and adjusts for part time and seasonal employment and for labour turnover. Thus, two workers each working six months of the year would be counted as one FTE job.

3 Results and discussion

3.1 Previous studies

A number of studies of the economic and jobs impacts of GHG control strategies have been conducted over the past decade, and they often reached different conclusions. The US Environmental Protection Agency (EPA) (2009) analysed the American Clean Energy and Security Act of 2009 (ACESA) – which mandated a GHG cap-and-trade policy, and its major findings included:

- 1 ACESA transforms energy production and consumption: Increased EE and reduced energy demand mean that energy consumption levels that would be reached in 2015 without ACESA are not reached until 2040 with ACESA.
- 2 The share of low- or zero-carbon primary energy rises substantially under ACESA to 18% of primary energy by 2020, 26% by 2030, and 38% by 2050, whereas without ACESA the share would remain at 14%. Increased EE and reduced energy demand reduces primary energy needs by 7% in 2020, 10% in 2030, and 12% in 2050.
- 3 The cap and trade policy has a relatively modest impact on US consumers. Average household consumption is reduced by 0.03% to 0.08% in 2015, 0.10% to 0.11% in 2020, and 0.31% to 0.30% in 2030, relative to the no policy case.

The US Congressional Budget Office (CBO) (2009) examined the average cost per household that would result from implementing the GHG cap-and-trade programme under ACESA and how that cost would be spread among households with different levels of income. According to CBO, the gross cost of complying with the GHG cap-and-trade programme would be about \$110 billion in 2020, or about \$890 per household. Taking into the account the costs of complying with the cap (\$110 billion), the allowance value that would flow back to US households (\$85 billion), and additional transfers and costs, the net economy-wide cost of the GHG cap-and-trade programme would be about \$22 billion – about \$175 per household.

The Brookings Institution (2009) estimated that ACESA would have severe impacts on the US economy. These include (2008 dollars):

- 1 An annual US GDP decrease of about 1.75% in 2030. This indicates that ACESA will reduce US GDP in 2030 by about \$430 billion – a loss of about \$3,100 per US household per year – and things get worse after 2030.
- 2 By 2018, ACESA would cause the loss of about 700,000 jobs.
- 3 Inflation would be 4% to 5% higher over the next two decades.
- 4 CO₂ prices would increase continuously: \$45/ton in 2020, \$80/ton in 2030, \$100/ton in 2040, and more than \$120/ton in 2020
- 5 Over the next four decades, ACESA would result in a wealth transfer via allowances of \$9.2 trillion.

The National Black Chamber of Commerce (NBCC) (2009) analysed the potential economic impacts of ACESA. The study examined those provisions related to GHG cap-and-trade, RE, and offsets, and focused on how these could affect the US economy. NBCC found that businesses and consumers would face higher energy and transportation costs under ACESA, which would lead to increased costs of other goods and services throughout the economy. As the costs of goods and services rise, household disposable income and consumption would decrease. Wages and returns on investment would also fall, resulting in lower productivity growth and reduced employment. Impacts would differ across regions, depending on how local energy costs will change, whether local industries will be favoured or harmed, and allocation formulas.

NBCC estimated that in 2015, unemployment would be 2.3 million higher than in the baseline and that there would remain 2.5 to 3 million fewer average jobs in the economy far into the future relative to what would otherwise have been possible. These estimated employment impacts are inclusive of all increases in ‘green jobs’ created by ASCEA.

A Coalition for Affordable American Energy (CAAE) (2009) report analysed the potential economic impacts of the climate provisions of the Obama Administration’s FY 2010 Budget Proposal. The report found that these provisions would have significant economic and energy market impacts and that market shares would shift within the energy sector. The results also indicated that businesses and consumers would face higher energy costs and the resulting higher energy costs increase the costs of goods and services throughout the economy. As these latter costs rise, household disposable income and consumption would fall. The cap and trade policy would cause more investment in costly forms of RE, thereby directing funding away from investments with greater potential to enhance productivity, and the economy would grow more slowly and job

growth would decline. Overall, the economy would be expected to grow more slowly, leading to substantial reductions in disposable income and personal consumption. By 2025, 3.2 million US jobs would be lost.

A Center for American Progress (CAP) (2008) report advocated a “green economic recovery program to strengthen the US economy”. This initiative was designed to expand job opportunities, stimulate economic growth, stabilise the price of oil, fight global warming, and build a green, low-carbon economy.

The report’s recommended green economic recovery programme would spend \$100 billion dollars over two years in green infrastructure investment areas, and would be paid for with proceeds from auctions of carbon permits under a GHG cap-and-trade programme. The authors estimated that the programme would create 2 million jobs by investing in EE and RE strategies. The report found that ‘green energy’ investments generate both more jobs than equivalent investments in other energy technologies and that these jobs also pay higher than average wages. It estimated that the programme would create 2 million new jobs and reduce the US unemployment rate by 25%.

A Heritage Foundation (2008) report estimated the economic impacts of Senate Bill 2191, ‘America’s Climate Security Act’, which imposes strict upper limits on the emission of six GHGs with the primary emphasis on CO₂, and would establish a cap-and-trade system. Heritage estimated the cost of S. 2191 at \$800 to \$1,300 per household by 2015, rising to \$1,500 to \$2,500 by 2050. Electricity prices could increase 36% to 65% by 2015 and 80 to 125% by 2050.

Heritage found that S. 2191 posed extraordinary perils for the US economy. Arbitrary restrictions predicated on untested and undeveloped technologies would lead to severe restrictions on energy use and large increases in energy costs. In addition to the direct impact on consumers’ budgets, these higher energy costs will spread through the economy and inject unnecessary inefficiencies at virtually every stage of production and consumption. Heritage found that implementing S. 2191 will be very costly:

- 1 Cumulative GDP losses are at least \$1.7 trillion and could reach \$4.8 trillion by 2030 (2006 dollars).
- 2 Single-year GDP losses total at least \$155 billion and could exceed \$500 billion (2006 dollars).
- 3 Annual job losses exceed 500,000, and could approach 1,000,000.

A report by the American Council for Capital Formation and the National Association of Manufacturers examined the costs that enactment of the Lieberman-Warner (LW) Climate Security Act (S. 2191) would impose on the US economy (American Council for Capital Formation and National Association of Manufacturers, 2008). The analysis found substantial impacts to consumers and the economy of meeting the increasingly stringent emission targets through 2030 established by LW:

- 1 the CO₂ emissions allowance price needed to reduce energy use to meet the S. 2191 targets is estimated at \$55–\$64/mtCO₂ in 2020, rising to \$227–\$271/mtCO₂ in 2030
- 2 the cost of the allowances raises energy prices for residential consumers by 100% or more by 2030
- 3 these increased costs slow the economy by \$151–\$210 billion in 2020 and \$631–\$669 billion in 2030 (2007 dollars).

This causes job losses of 1.2–1.8 million in 2020 and 3–4 million by 2030. The study's key finding is that S. 2191 would cause significant job losses: In 2020, job loss is projected to range from 1.2 million to 1.8 million jobs/year, and from 3 million jobs to 4 million jobs in 2030. These job losses are net of the new jobs which may be generated by increased spending on RE, EE, and carbon capture and storage.

From even a brief summary review of these studies, it is clear that different investigations reached very different conclusions and that there is little consensus on how these issues should be analysed. Not surprisingly, studies sponsored by organisations opposed to GHG control policies found that such policies would harm the economy and destroy jobs, whereas studies sponsored by organisations favouring such policies came to different conclusions. Analytically, the research findings often differed based on the assumptions made, the economic models employed, whether the analysis assessed the overall net effects of the policy changes, the time horizon considered, the technologies specified, the price elasticities utilised, the scale of the energy perturbations simulated, the substitution possibilities allowed, the labour market flexibility modelled, and various other factors. While a detailed assessment of the studies is outside the scope of the present paper, it is clear that there is general agreement that implementation of meaningful GHG control policies will have major economic and energy market impacts. In our work, we tried to accurately model the economic and job impacts of GHG reduction strategies by:

- 1 utilising technology and cost data that had been independently estimated and verified in a comprehensive study
- 2 employing realistic supply and learning curves
- 3 using standard life cycle cost methodology
- 4 including both positive and negative economic and job impacts to derive the net impacts
- 5 using an empirical modelling approach that has been vetted in the literature and successfully used over the past three decades to analyse a wide variety of programmes, initiatives, and policy perturbations.

3.2 Economic and jobs estimates for 2020 and 2030

3.2.1 Summary of the cost and jobs estimates

To address the potential costs of the TCC initiative, analysts examined the technology costs estimate provided in the TCC report (Kutscher, 2008). To estimate the equivalent annual cost of deploying each technology, they considered the deployment curve for each, and then estimated how much each amount of deployment would cost in the year deployed.

For each technology, they took into account supply curves (which show how costs increase as less ideal resources are tapped) as well as R&D and learning curves (which indicate how costs decline with R&D improvements and experience). RE plants and EE measures deployed in any year will contribute energy for 25 years or more into the future, and standard life-cycle cost analysis was used to derive an equivalent annual cost of all

that energy per year for each technology. Finally, current and projected costs of the conventional energy displaced were subtracted to derive the net cost.

Table 2 and Figures 5, 6, and 7 summarise the net costs and jobs impact of the TCC initiative in 2020 and 2030. Table 2 illustrates that the net costs of the EE and RE components of the TCC initiative differ dramatically among technologies and over time. For example, in 2020, the net costs are $-\$67$ billion; in 2030, the net costs are $+\$4$ billion; in 2020, EE has net savings of $\$85$ billion, while all of the RE technologies except biofuels have net costs; in 2030, EE has net savings of $\$17$ billion, while all of the RE technologies except wind and biofuels have net costs. The net savings from EE decline significantly over the forecast period, from $\$85$ billion in 2020 to $\$17$ billion in 2030: Biofuels net savings increase from -1 billion in 2020 to $-\$8$ billion in 2030; biomass costs increase from $\$3$ billion in 2020 to $\$4$ billion in 2030; PV costs increase nearly three-fold, from $\$5$ billion in 2020 to $\$16$ billion in 2030; concentrating solar costs decrease 60%, from $\$5$ billion in 2020 to $\$2$ billion in 2030; geothermal costs increase by over one-half, from $\$4$ billion in 2020 to almost $\$7$ billion in 2030. Annualised costs over the entire period also differ dramatically, from a $-\$108$ billion for EE to more than $\$9$ billion for biofuels and nearly $\$7$ billion for concentrating solar

Table 2 Net costs and jobs resulting from the TCC initiative

	<i>Net costs</i>			<i>Net jobs</i>	
	<i>Annualised</i>	<i>2020</i>	<i>2030</i>	<i>2020</i>	<i>2030</i>
	<i>Billion 2005 dollars</i>			<i>Thousand FTE</i>	
Energy efficient	$-\$107.9$	$-\$84.8$	$-\$17.4$	3,533	3,360
Wind	$\$0.0$	$\$0.3$	$-\$0.4$	149	93
Biofuels	$\$9.2$	$-\$0.5$	$-\$7.6$	261	257
Biomass	$\$2.6$	$\$3.3$	$\$4.5$	122	172
Photovoltaics	$\$4.7$	$\$5.3$	$\$16.0$	105	340
Concentrating solar	$\$6.6$	$\$5.2$	$\$2.2$	156	147
Geothermal	$\$2.5$	$\$4.0$	$\$6.7$	96	144
Total	$-\$82.3$	$-\$67.2$	$\$4.0$	4,419	4,513

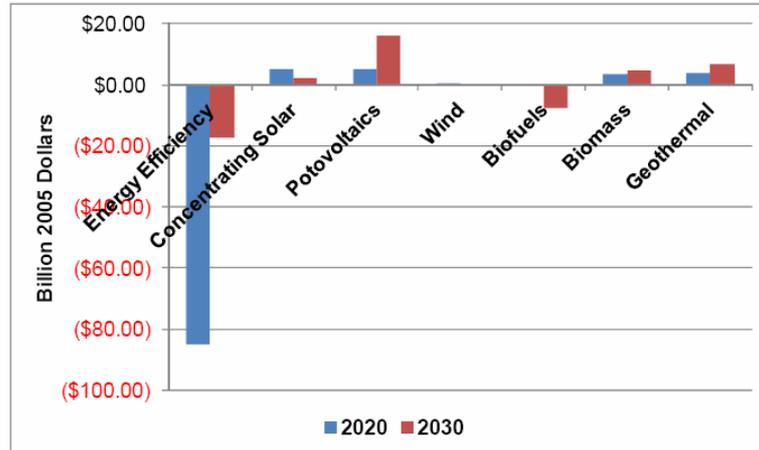
Source: American Solar Energy Society (2007)

Table 2 and Figures 6 and 7 show that the EE component of the TCC initiative generates many more jobs than does the RE component: In 2020, EE generates more than 3.5 million net jobs, compared to less than 900,000 generated by RE; in 2030, EE generates more than 3.3 million net jobs, compared to 1.15 million generated by RE; in 2020, 80% of the total net jobs created by the TTC initiative are generated by the EE component; in 2030, 74% of the total net jobs created by the TTC initiative are generated by the EE component.

Net job generation differs significantly among the RE components – by technology and time period: In 2020, the most jobs are generated by biofuels (261,000), followed by concentrating solar (156,000), wind (149,000), biomass (122,000), PV (105,000), and geothermal (93,000); in 2030, the most jobs are generated by PV (105,000), followed by biofuels (257,000), biomass (172,000), concentrating solar (147,000), geothermal (144,000), and wind (93,000); In 2030, more jobs are generated than in 2020 for biomass,

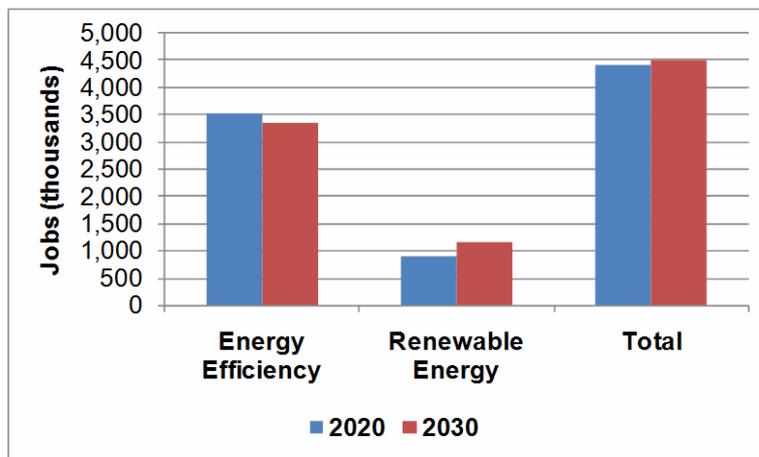
PV, and geothermal; in 2020, more jobs are generated than in 2030 for wind, biofuels, and concentrating solar.

Figure 5 Net costs resulting from the TCC initiative (see online version for colours)



Source: American Solar Energy Society (2007)

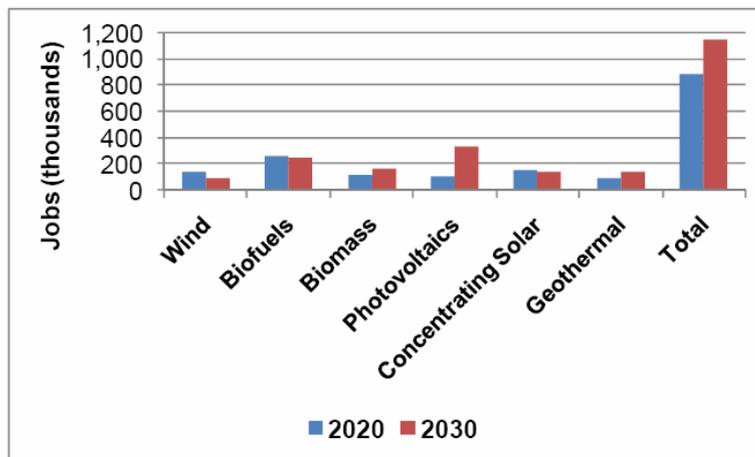
Figure 6 EE and RE jobs created by the TCC initiative (see online version for colours)



We thus estimate that the TCC initiative, while requiring deployment costs in most years for most alternate energy technologies, would have an overwhelmingly positive impact on the US economy. We found that the impact of the TCC initiative would account for: Growth in the wind energy industry that would peak in 2012 and still account for a net addition of 149,000 jobs to the US economy in 2020 and 93,000 jobs in 2030; a biofuels industry impact growing slowly throughout the period, accounting for 261,000 jobs in 2020 but dropping to 257,000 jobs by 2030; a biomass industry impact growing strongly during the period resulting in a net addition of 122,000 jobs in 2020 and 172,000 in 2030; a slowly growing photovoltaics industry impact of 105,000 jobs in 2020 that accelerates

rapidly in the 2020s resulting in a net employment impact of 340,000 by 2030; a steady growth in the impact on the concentrating solar power industry that is beginning to peak in 2030, but accounting for 156,000 jobs in 2020 and 147,000 jobs in 2030; consistent impacts to the geothermal industry, with net jobs growing by 93,000 in 2020 and by 144,000 by 2030; rapid growth impacts in the EE industry that would begin immediately and peak in 2025, but in 2020 account for over 3.5 million net jobs and almost 3.4 million net jobs in 2030.

Figure 7 RE jobs created by the TCC initiative (see online version for colours)



3.2.2 *Employment by Industry*

The jobs impacts by industry of the TCC initiative are shown in Tables 3 and 4 and Figure 8. Examining the net jobs generated by industry from TCC initiative indicates that the impacts are well-distributed throughout the US economy. The industries involved are not surprising, and they will be instrumental in the transformation to a new energy consumption structure and subsequent economic growth. The top industries showing the largest jobs impacts in 2030 are listed in order with the part they will play; for example, construction – the industry received an overwhelming direct stimulus from almost all the growing EE and RE sector technologies, in addition to a positive indirect impact from the improvement in overall economic growth due to energy savings; professional, scientific, and technical services – the industry plays a large part in driving the new energy and EE technologies; electrical equipment, appliances, and components – the industry will be relied upon to supply not only new electrical components and testing equipment to all the alternative electric energy technologies, but will also contribute to efficiencies in the smart grid from generation to final consumer use; fabricated metal products – the industry will be the primary supplier of parts, products, and systems for the photovoltaic, wind, and concentrating solar technologies; motor vehicles and parts – the industry will be positively affected by transportation energy improvements that will stimulate R&D and vehicle sales as the country's rolling stock turns over; computer systems design and related services – the industry will be stimulated by the smart grid and other EE applications (Uddin and Rahman, 2011).

Table 3 Net jobs by industry generated by the TCC initiative in 2020 (top 24 industries)

<i>Industry</i>	<i>Jobs (thousands)</i>
Construction	642
State and local general government	279
Professional, scientific and technical services	247
Farms	237
Retail trade	189
Administrative and support services	168
Truck transportation	166
Other services, except government	145
Waste management and remediation services	137
Fabricated metal products	137
Electrical equipment, appliances, and components	135
Non-metallic mineral products	135
Other transportation and support activities	130
Miscellaneous manufacturing	117
Wholesale trade	111
Food services and drinking places	110
Forestry, fishing, and related activities	109
Motor vehicles and parts	75
Primary metals	65
Chemical products	63
Computer systems design and related services	53
Management of companies and enterprises	53
Other transportation equipment	52
Real estate	47
Total: all industries (including those not listed)	4,419

Figure 8 Net jobs by industry generated by the TCC initiative in 2020 and 2030 (selected industries) (see online version for colours)

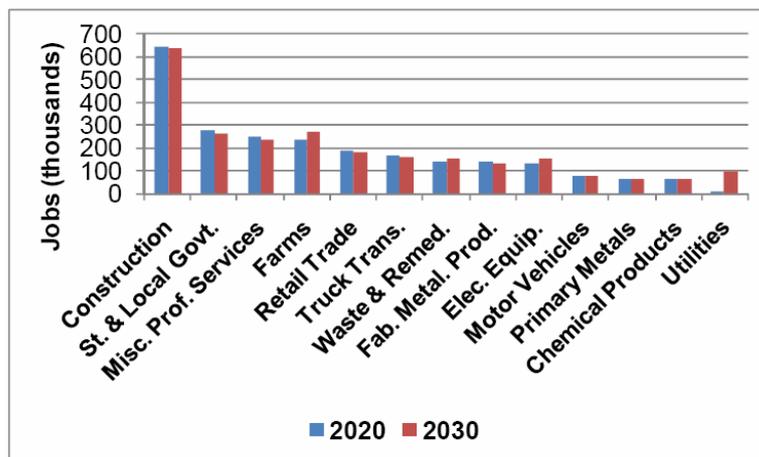


Figure 8 shows that, while about 100,000 more net jobs are created in 2030 than in 2020, this varies among industries: In some industries, more net jobs are created in 2030 than in 2020 – these include farms, waste management and remediation services, electrical equipment and components, and utilities; in some industries, more net jobs are created in 2020 than in 2030 – these include construction, state and local government, miscellaneous professional, scientific, and technical services, retail trade, and truck transportation; in some industries, about the same number of net jobs is created in 2030 as in 2020 – these include motor vehicles and parts, primary metals, and chemical products.

Table 4 Net jobs by industry generated by the TCC initiative in 2030 (top 24 industries)

<i>Industry</i>	<i>Jobs(thousands)</i>
Construction	636
Farms	272
State and local general government	263
Miscellaneous professional, scientific and technical services	233
Retail trade	178
Truck transportation	161
Administrative and support services	161
Waste management and remediation services	152
Electrical equipment, appliances, and components	151
Miscellaneous manufacturing	142
Other services, except government	142
Fabricated metal products	132
Forestry, fishing, and related activities	132
Non-metallic mineral products	129
Other transportation and support activities	120
Wholesale trade	107
Food services and drinking places	101
Utilities	96
Motor vehicles, bodies and trailers, and parts	76
State and local government enterprises	70
Computer systems design and related services	68
Primary metals	65
Chemical products	61
Other transportation equipment	52
Total: all industries (including those not listed)	4,513

3.2.3 *Jobs by occupation and skill*

There exists little rigorous research addressing the relationship between EE&RE climate change mitigation initiatives and current and future jobs. Even some research in this area is off the mark, in that it tends to emphasise jobs creation in classically green activities,

such as EE&RE specialists or workers in recycling plants. However, while these jobs certainly count as jobs related to EE&RE and to climate change mitigation, MISI's research suggests that these types of jobs constitute only a small portion of the jobs created. The vast majority of the jobs created by EE&RE are standard jobs for accountants, engineers, computer analysts, clerks, factory workers, truck drivers, mechanics, etc. In fact, most of the persons employed in these jobs may not even realise that they owe their livelihood to EE&RE.

There are thousands of EE&RE companies located throughout the USA, and they generate millions of jobs. Given the wide diversity in the size, function, and technologies of these companies, it is impossible to estimate the job profile of the 'average' EE&RE firm. However, it is possible to identify the jobs and earnings profiles of typical types of firms involved in EE&RE-related areas of work.

First, firms working in the EE&RE and related areas employ a wide range of workers at all educational and skills levels and at widely differing earnings levels. Second, in EE&RE companies, few of the employees are classified as RE or EE specialists. Most of the workers are in occupations such as machinists, engineers, bookkeepers, accountants, maintenance workers, cost estimators, etc. All of these employees owe their jobs and livelihoods to EE&RE, but, in general, they perform the same types of activities at work as employees in firms that have little or nothing to do with EE&RE or climate mitigation activities.

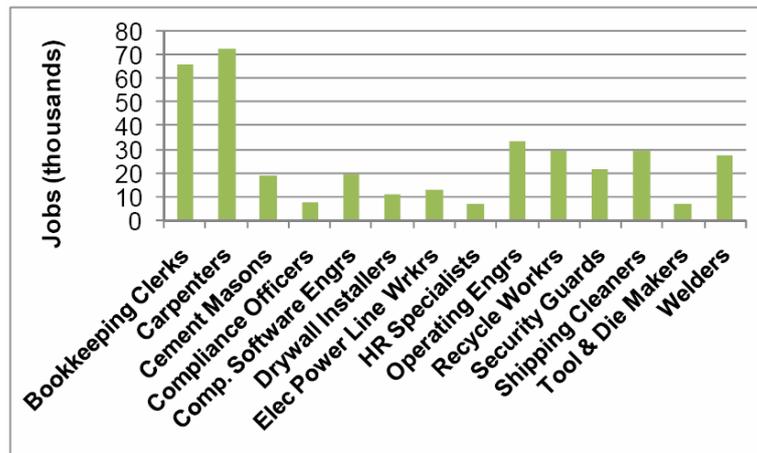
For example, the occupational job distribution of a typical wind turbine manufacturing company differs relatively little from that of a company that manufactures other products. Thus, the production of wind turbines and turbine components requires large numbers of engine assemblers, machinists, machine tool operators, mechanical and industrial engineers, welders, tool and die makers, mechanics, managers, purchasing agents, etc. These are 'RE' workers only because the company they work for is manufacturing a RE product. Importantly, with the current national angst concerning the erosion of the US manufacturing sector and the loss of US manufacturing jobs, it is relevant to note that many RE technologies are growing rapidly. These types of firms can help revitalise the manufacturing sector and provide the types of diversified, high-wage jobs desired.

More generally, while traditional debate on alternative energy has focused on applying new technology to offset traditional energy sources, EE&RE is more than a source of fuel or energy savings. It is source of jobs. As shown here, employment growth in the EE&RE industry varies for the different segments of the industries, but new breakthroughs in EE&RE technologies will come from the growing sectors of the industry, including architectural and engineering services, materials processing, and R&D. In addition, utilities are an area for pioneering a number of alternative energy technologies, including superconducting power lines which reduce the 20% loss of electricity due to transmission, solar thermal, photovoltaic, and wind systems, and distributed power technologies which will reduce the losses from transmission and supply more reliable localised power and enable power production all across the electrical grid. Increasingly, however, EE&RE advances will come from all areas of the economy, and may not necessarily be captured by traditional energy technologies (Mandal et al., 2011).

Thus, the vast majority of the jobs created by EE&RE are standard jobs for accountants, engineers, computer analysts, clerks, factory workers, truck drivers, mechanics, etc. and most of the persons employed in these jobs may not even realise that

they owe their livelihood to EE&RE. This is illustrated in Table 5 and Figure 9, which show the jobs created by the TCC initiative in 2020 and 2030 within selected occupations. These demonstrate that the TCC initiative will generate: More jobs for cashiers than for recyclable materials collectors; more jobs for order clerks than for architects; more jobs for executive secretaries than for waste treatment plant operators; more jobs for janitors than for civil engineers; more jobs for customer service representatives than HVAC mechanics and installers; more jobs for truck drivers than for plumbers; more jobs for stock clerks than for electrical and electronics engineers; more jobs for customer service representatives than for welders; more jobs for inspectors and testers than for sheet metal workers; more jobs for bookkeeping and accounting clerks than for mechanical engineers. Thus, many workers will be dependent on the TCC initiative for their jobs, although they often would have no way of recognising the connection unless it is brought to their attention.

Figure 9 Net jobs by occupation generated by the TCC initiative in 2030 (selected occupations) (see online version for colours)



Occupational data demonstrate that the TCC initiative will create a variety of high-paying jobs, many of which take advantage of manufacturing skills currently going unused as US manufacturing stagnates. As shown in Table 6, wages and salaries in many sectors of the EE&RE and related industries are higher than US average wages. Although many high-tech industries almost exclusively require highly educated workers with masters or doctoral degrees, as noted, the EE&RE industry requires a wide variety of occupations. Nevertheless, many occupations in the EE&RE industry include jobs which require associate's degrees, long-term on-the-job training, or trade certifications, including engineers, chemists, electrical grid repairers, power plant operators and power dispatchers, chemical technicians, mechanical engineering technicians, and EE&RE technicians, all of which pay higher than US average wages.

Table 5 Net jobs by occupation generated by the TCC initiative in 2030 (selected occupations)

<i>Industry</i>	<i>Jobs (thousands)</i>
Agricultural equipment operators	12
Architects	5
Bookkeeping and accounting clerks	66
Carpenters	73
Cashiers	44
Cement masons and concrete finishers	19
Compliance officers	8
Computer software engineers	20
Computer systems analysts	17
Cost estimators	16
Customer service representatives	64
Drywall installers	11
Electricians	49
Electric power line workers	13
Farm workers and labourers	142
Financial analysts	6
Hazardous materials removal workers	14
Human resource specialists	7
Industrial engineers	14
Industrial production managers	11
Operating engineers	34
Painters	19
Plumbers	35
Power plant operators	5
Purchasing agents	14
Refuse and recyclable material collectors	30
Security guards	22
Sewer pipe cleaners	6
Shipping and receiving clerks	30
Structural iron and steel workers	5
Tool and die makers	7
Waste treatment plant operators	8
Welders and solderers	28

Table 6 RE, EE, and related occupations: wages, educational requirements, and growth forecasts (selected occupations)

<i>Occupation</i>	<i>10 year % growth forecast</i>	<i>Median salary</i>	<i>% with bachelor's degree</i>	<i>Education</i>
Materials scientists	8	\$75,800	94	Bachelor's
Physicists	7	93,300	92	Doctoral
Microbiologists	17	64,600	96	Doctoral
Biological technicians	17	37,200	60	Associate
Conservation scientists	6	54,800	88	Bachelor's
Chemists	7	64,800	94	Bachelor's
Chemical technicians	4	40,900	27	Associate
Geoscientists	6	74,700	94	Doctoral
Natural science managers	14	101,000	90	Bachelor's
Environmental eng. technicians	24	42,800	18	Associate
Soil and plant scientists	20	59,100	64	Bachelor's
Mechanical eng. technicians	12	47,400	18	Associate
Environmental sci. technicians	16	39,100	47	Associate
Biomedical engineers	31	76,900	60	Bachelor's
Chemical engineers	11	80,800	92	Bachelor's
Mechanical engineers	10	78,600	88	Bachelor's
Electrical engineers	12	77,700	83	Bachelor's
Environmental engineers	14	76,000	82	Bachelor's
Computer scientists	26	95,900	67	Doctoral
Life and physical sci. technicians	20	46,100	50	Associate
Utility plant operatives	4	54,100	10	OJT
HVAC technicians	12	38,300	14	OJT
Energy audit specialists	18	40,300	18	OJT
Forest and conservation workers	6	27,500	8	OJT
Refuse and recycling workers	5	26,400	2	OJT
Insulation workers	6	\$30,800	2	OJT

Source: US Bureau of Labor Statistics (2012)

While Table 6 indicates that many of the jobs created to abate global warming will be relatively high paying, it must be noted that future real wages will depend on future labour productivity – which is closely related to the productivity of energy sources (energy return on energy invested). A key challenge will be to ensure that labour productivity, and consequently real wages, will increase with a significant shift to low-

carbon energy sources. This is not assured, even with a major effort to address global warming such as that detailed in TCC. Indeed, in the USA over the past two decades real wages have stagnated even in the absence of a concerted effort to address the global warming issue. Further, as noted, while global warming abatement policies such as those detailed here can create many high paying jobs, most of the jobs created will be standard jobs for accountants, analysts, clerks, factory workers, security guards, truck drivers, mechanics, janitors, etc. whose real wages may be stagnant or increase very slowly. Thus, global warming abatement policies may be a necessary, but not sufficient part of the economic equation and this issue is deserving of further research.

4 Conclusions

The potential costs and jobs impacts of climate change mitigation policies are relevant and highly contentious. Numerous studies have been published contending that such policies could cost the US trillions of dollars and millions of jobs over the next several decades, and there exists substantial skepticism concerning the impacts of these policies. For example, former Federal Reserve Board Chairman Alan Greenspan cautioned that “Cap-and-trade systems or carbon taxes are likely to be popular only until real people lose real jobs as their consequence” (Greenspan, 2007). Further, the USA is currently trying to extricate itself from the worst economic recession in seven decades and continues to suffer from record high unemployment. Thus, the economic and jobs impact of climate change mitigation policies is a legitimate issue.

The TCC report described how EE&RE technologies, in an aggressive but achievable scenario, can provide significant US carbon reductions by 2030. The research reported here indicates that effective and economically beneficial GHG mitigation policies can be developed. The TCC initiative involves ambitious, aggressive programmes in the areas of EE and RE that can, by 2030, effectively reduce US carbon emissions, have total, cumulative net costs of near zero, and generate more than 4.5 million net jobs.

It is important to note that the jobs estimate here is net jobs. Any ambitious climate change mitigation programme will both create jobs and will cause job losses in different sectors, industries, and occupations. However, we estimate that, in total, more than 4.5 million more jobs will be created by the TCC initiative than will be lost. These jobs will be widely dispersed throughout the US in virtually all industries and occupations. Thus, the major conclusion of this study is that climate mitigation initiatives can be a major net job creator for the US economy.

A major solution to the global warming problem will be much more extensive use of EE and RE technologies. Our findings indicate that this solution to global warming will have positive economic and job impacts in the USA.

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Nomenclature

ACESA	American Clean Energy and Security Act of 2009
ASES	American Solar Energy Society
CAAE	Coalition for Affordable American Energy
CAP	Center for American Progress
CBO	US Congressional Budget Office
CO ₂	Carbon dioxide
EE	Energy efficiency
EE&RE	Energy efficiency and renewable energy
EPA	US Environmental Protection Agency
FTE	Full-time-equivalent
GDP	Gross domestic product
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
LW	Lieberman-Warner
MISI	Management Information Services, Inc.
mtCO ₂	Million tons of CO ₂
MW	Megawatt
NBCC	National Black Chamber of Commerce
OJT	On the job training
R&D	Research and development
RE	Renewable energy
PV	Photovoltaic
TCC	Tackling climate change
