The Statewide Job Generation Impacts of Expanding Industrial CHP

Gyungwon Kim, Paul Baer, and Marilyn A. Brown,
Georgia Institute of Technology

Conference Paper presented at
2013 American Council for an Energy-Efficient Economy (ACEEE)
Summer Study on Energy Efficiency in Industry,
July 23-26, 2013, Niagara Falls, NY

ABSTRACT

As indicated by a recent executive order that set a national goal of 40 GW of new combined heat and power (CHP) by 2020, CHP is a key energy-efficient technology, especially for industrial businesses. However, the deployment of CHP is challenging because private firms, particularly in the industrial sector, face financial, regulatory, and workforce barriers. This discrepancy between private and public interest could be minimized by policies promoting "energy-based economic development." In this context, much effort has gone into promoting "green jobs," a politically attractive but rather vague term. We have developed methods to address the energy-jobs connection through a hybrid approach combining simulations using the National Energy Modeling System (NEMS) with Input-Output (I-O) modeling to estimate the employment impacts from sectoral perspectives. We identify the first-order employment impacts by creating a "bill of goods" that matches the expenditure on installation and operation of CHP with the industrial sectors affected by the expenditures; we additionally calculate second-order impacts based on the redirection of energy-bill savings accruing directly or indirectly to consumers. Building on earlier work use downscaling methods to estimate the differential state-level impacts of an expansion of industrial CHP, modeled as the result of a 20% Investment Tax Credit. The addition of 13.6 GW of industrial CHP by 2035 is estimated to produce a net annual increase in jobs growing from 21,400 (in the 2015-2019 timeframe) to 33,800 (averaged between 2030 and 2034). These employment estimates include significant second-order impacts, which are often overlooked in the green jobs literature.

CLIMATE AND ENERGY POLICY LABORATORY
SCHOOL OF PUBLIC POLICY

Introduction

Improving energy efficiency in the industrial sector is often regarded as a critical agenda for energy policy. In the United States, the industrial sector is the largest consumer of energy, accounting for 31 percent of all energy consumed in 2010, with further increases expected over the next 25 years (U.S. EIA, 2012). To encourage industries to adopt cleaner and more efficient energy sources, the Obama Administration announced a recent executive order (August 2012) that accelerates investments in energy-efficient technologies in manufacturing. The ultimate goals behind this order include energy cost reductions, air pollution mitigation, and job creation. Combined heat and power (CHP) is a targeted technology. The executive order has set a national goal of 40 GW of new industrial CHP by 2020, directing a broad set of stakeholders including states, manufacturers, and utilities (The White House, 2012).

CHP has been considered a key energy-efficient technology, especially for industrial consumers, because this cogeneration system allows manufacturers to reuse by-product heat for heating purposes and to avoid energy losses through the process of generating both electricity and useful heat in an integrated system (Shipley et al., 2008). By capturing the waste heat, the efficiency of conversion can be increased from 45 percent in typical thermal power plants to as much as 80 percent in efficient natural gas CHP facilities (Shipley et al., 2008). CHP is also a system of distributed generation that allows manufacturers to contribute to system resilience through reducing electricity purchased from the central utility and producing excess power to sell back to the grid. These characteristics make CHP especially attractive for industrial users who want to enjoy the benefits of site-specific, strategic energy production to supply their electricity and thermal energy needs. However, the return on investment from CHP investments is especially sensitive to the price of natural gas, as shown in a recent analysis of risk factors influencing the cost-effectiveness of industrial energy-efficiency policies including an ITC for CHP (Brown, et al., 2013). Currently, cogeneration is especially common in pulp and paper mills, refineries, food processing, and chemical plants (Sentech Inc., 2010).

While the benefits of CHP deployment are large for both industrial consumers and society, meeting the 40 GW goal of the executive order may be difficult without policy intervention. According to the reference case forecast of the National Energy Modeling System (NEMS),[1] the nation's industrial CHP capacity would increase from 35 GW in 2012 to 50 GW in 2020 in non-refining industrial CHP, meeting only 47% of the executive goal.[2] This baseline case already reflects the current (through 2016) federal Investment Tax Credit (ITC) policy that subsidizes 10 percent of installation costs for qualified CHP systems up to 50 MW in capacity.

Many studies have characterized the numerous barriers that hamper the widespread deployment of CHP technologies (Chittum & Kaufman, 2011l; CCCSTI, 2009; Shipley et al., 2008; U.S. EPA, 2012). In particular, the high upfront cost of CHP installations and long payback periods compared to traditional equipment impose a substantial financial barrier; and

[1] This paper uses NEMS as a principal energy modeling system. The baseline projections of NEMS are generated from EIA's Annual Energy Outlook 2011, which is regarded as a reliable representation of the U.S. energy market.

[2] In NEMS, the industrial CHP capacity, which is modeled in the Industrial Demand Module, does not include the CHP capacity installed by petroleum refining industry that is separately modeled in the Petroleum Market Module. Therefore, we recalculate the executive goal excluding the petroleum refining industries. Assuming that an equal proportion of refining CHP capacity to the present level (23%), the executive goal can imply 31 GW of new capacity by 2020.

the current economic downturn in the U.S. has caused companies to have even greater aversion to longer payback periods, compounded by difficulties securing financing (Chittum & Kaufman, 2011).

In our earlier publication (Baer, Brown and Kim 2013), we estimated the relative impacts of a sizeable increase of CHP capacity, driven by expanding the federal ITC to 10, 20, and 30 percent without the 50 MW cap through 2035. Our analysis recognizes that subsidies can produce changes in energy consumption, production, and prices across the economy, including the industrial, residential, and commercial sectors. When the full array of climate change and air quality benefits is considered, the return on the public investment is highly favorable. While the annual deadweight loss of the proposed federal CHP policy is estimated to range from $30 million to $150 million (2008-$), that is much smaller than the estimated annual social surplus of $150 million to $4.8 billion (Brown, Cox, and Baer, 2013). By combining an Input-Output (I-O) model with the projections of an energy systems model (NEMS), we develop a hybrid analytical tool to generate plausible estimates of the consequences of various policy, price, and technology scenarios.

In this paper, we focus in particular on the state-by-state variance of CHP installation and its impacts on energy market dynamics and job creation. NEMS provides output data for projected CHP capacity increases at the US Census Region level (four Regions), energy prices and consumption at the Census Division level (nine Divisions), and electricity prices and consumption at the NERC sub-region level (22 subregions). Taking a single scenario (20% ITC) from our earlier analysis and comparing it with the reference case, we use available data (both historical and projected) to apportion both the new CHP capacity and the resulting employment changes to states. We focus on four sample states with large or rapidly growing CHP capacity, and use some simple downscaling methods to assess the variability of impacts. We see this work as contributing to a more comprehensive state-centered analytical capacity that can examine interacting effects of energy-based economic development (Carley et al. 2011) at state and national levels.

Overview of CHP Installations and Policy Environment by State

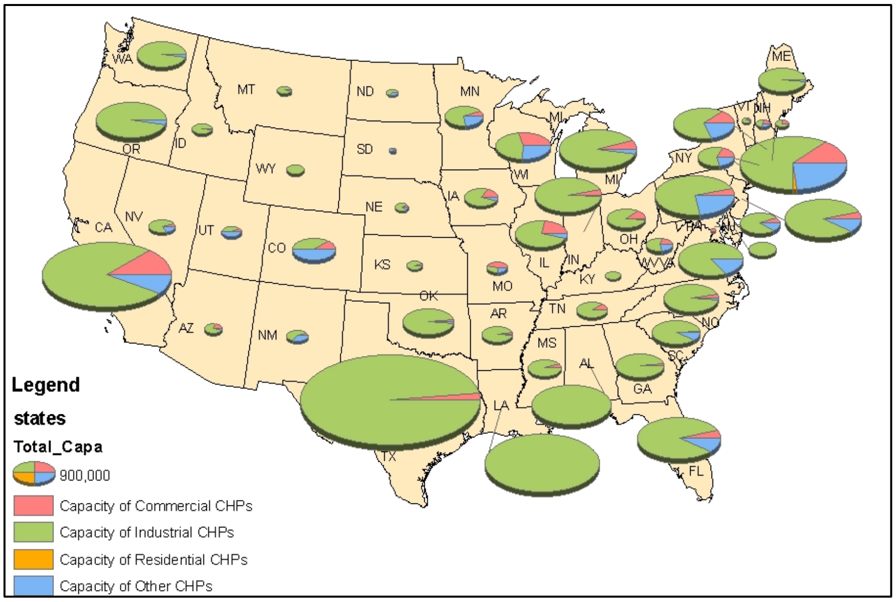
ICF International has established a CHP installation database [3] that contains comprehensive information about U.S. CHP facilities by state, by application, and by year. In 2010, a total of 3,660 facilities operated CHP systems with 83.7 GW in generating capacity. Using the NAICS code category in the database, the industrial sector accounts for 86% of national CHP capacity, primarily in three manufacturing industries—chemicals (24 GW), refining (15 GW), and pulp and paper mills (12 GW)—as well as other industries. Of the 3,660 operating facilities, 633 sites totaling 2.2 GW were installed in the last 5 years.

These industrial CHP installations show geographically uneven distribution from state to state, following the variance of statewide regulatory and market landscapes. Figure 1 illustrates the regional distribution of operating CHP. Some states—Texas, California, Louisiana, and New York—have built a large amount of CHP capacity, as shown by the size of the pie charts. CHP capacity is generally greatest in states with the largest industrial base that rely on both thermal and electrical energy. Texas and Louisiana have the two largest concentrations of CHP capacity because of their major industries—chemicals and petroleum refining. On the other hand,

[3] We used the CHP installation database updated in March, 2011. (Source: http://www.eea-inc.com/chpdata/)

California and New York apply CHP systems with a wider range of purposes not only because of their large industrial demand but also because of effective statewide policies and output-based emissions regulations (Shipley et al., 2008).

Figure 1. Regional Distribution of CHP Capacity by Sectors, 1900-2010
(Source of data: ICF International, 2011)



While California, Texas, and New York have been leading states for a long time, Connecticut became a new leader in both the industrial and commercial building sectors in the last five years. Even though Connecticut's total CHP capacity is not as much as those in the other leading states, they have established CHP at multiple scales in diverse fields. As Table 1 shows the states with the most new CHP capacity per million dollars of gross state product (GSP), Connecticut relies highly on CHP systems to meet their new energy demand. In this study, we focus on these four states to estimate employment impacts from the growth of CHP deployment.

To foster additional CHP deployment, the favorable regulatory and policy environments led by state governments could be critical. The ACEEE's *State Energy Efficiency Scorecard* (Foster et al., 2012; Sciortino et al., 2011) evaluates states' adoption of CHP policies since 2006. Many of the states discussed above have actively sought to remove market barriers with favorable regulatory policies, and to create a market environment that promotes the deployment of CHP. State efforts include establishing interconnection standards, CHP-friendly standby rates, financial incentive programs, output-based environmental standards, net metering regulations, CHP credit in a renewable portfolio standard and energy efficiency resource standard, and other policies that can impact the attractiveness of CHP projects (Chittum & Kaufman, 2011; Foster et al., 2012). According to the Scorecard's assessment, three of the top states for industrial CHP installation—Texas, California, and New York— received 4 out of 5 points for having a CHP supportive environment while Louisiana earned zero (Foster et al., 2012). In contrast, Connecticut has continuously obtained the top score since 2008. These high-scoring states have developed supportive policies and standards for CHP installation. For example, Texas, California, New York, and Connecticut established strong interconnection standards beneficial to smaller sizes of CHP systems. Texas, California, and Connecticut implement output-based emissions regulations that provide credit for the thermal output of highly efficient CHP systems. New York and California maintained high CHP deployment in recent years because of their strong financial incentives and technical assistance programs. In particular, California is famous for its Self-Generation Incentive Program that provides rebates for clean distributed generation systems. As a result, these active states have seen substantial growth in CHP capacity in diverse end-user sectors including industrial, commercial, and other sectors [4] (ICF International, 2011).

Table 1. State Leaders in New CHP Installation, 2005-2010
(Source of data: a - ICF, 2011; b - IMPLAN; c - Foster et al., 2012)

States	Total Capacity (kW) [a]	Industrial Capacity with refining (kW) [a]	Industrial Capacity without refining (kW) [a]	Number of Total Sites [a]	Number of Industrial Sites [a]	Gross State Product ($ Million 2010) [b]	kW/ $Million	ACEEE Score in 2012[c]
California	438,000	319,000	19,000	153	25	1,910,000	0.229	4
Texas	438,000	357,000	225,000	10	3	1,290,000	0.340	4
Connecticut	202,000	80,000	80,000	69	16	230,000	0.880	5
New York	111,000	3,000	3,000	107	6	1,150,000	0.097	4

Method for Estimating the Employment Impact of CHP Capacity Growth

This study aims to assess the employment impacts of an increase in the deployment of CHP systems, in this case through an expanded ITC policy. In addition, we examine how the federal investments cause regional variance in job creation. To investigate the relationship between energy efficiency investments and energy market dynamics, we have developed an analytical model to combine regional energy market projections derived from NEMS with sectoral employment coefficients taken from Input-Output (I-O) modeling. State-specific impacts are estimated using a proportioning method mainly based on the State Energy Data System (SEDS) and state population projected by the U.S. Census Bureau. Reflecting state leadership discussed above, the statewide employment impacts are calculated for four target leader states—California, Connecticut, New York, and Texas.

National Energy Modeling System. Clean energy policies and investments are first modeled in NEMS, which is well suited to projecting how alternative energy policies might impact energy consumption and prices over time, particularly with respect to CHP systems, because it has a detailed methodology for evaluating the market penetration of CHP technologies in different subsectors of industry. NEMS' "bottom-up" technology configuration enables an assessment of technology investments, energy prices, energy consumption and expenditures, carbon abatement, and pollution prevention over time and across regions of the U.S. Because we have modified the input cost assumptions of NEMS, we relabeled it the Georgia Tech – National Energy Modeling System (GT-NEMS).

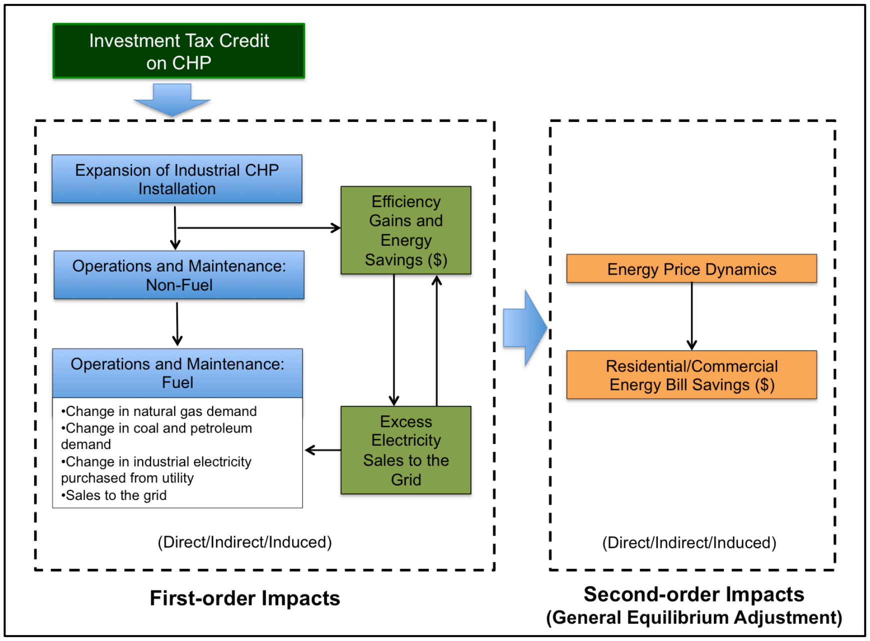
[4] Other sectors with CHP applications include solid waste treatment, wastewater treatment, and utilities.

In this study, focusing on industrial CHP end-users, a policy scenario of expanded ITC was evaluated using GT-NEMS, assuming subsidies of 20 percent from 2015 to 2035 across all type of CHP systems. The results for the scenario provide estimates of changes in CHP capacity, natural gas consumption, electricity purchased from the grid and sales back to the grid, and energy prices by sector. The differences between the reference case and the 20% ITC allow estimation of net jobs from installation and operation of additional CHP and the recycling of economy-wide energy-bill savings.

Input-Output Modeling and First Order Impacts. Any employment study, whether focused on a project or a policy, has to specify the boundaries of the analysis and the pathways of employment impacts (positive or negative) that will be included. I-O modeling has developed a conventional language referring to direct, indirect, and induced employment, where direct employment is based on additional final demand for products from particular sectors, indirect employment is based on expenditures for intermediate goods by the sectors seeing increased final demand, and induced employment is based on the additional expenditure by persons earning wages and profits from the additional production (Miller and Blair, 2009). We classify all of these as *first order* impacts, as they are based on partial-equilibrium effects in which all prices and technological coefficients are assumed to stay constant.

Subsets of First-Order Impacts. We model three different categories of first-order impacts: one-time jobs in construction, installation and manufacturing (CIM), and "permanent" (or "annual") jobs based on the operation of the new capacity and the corresponding changes in energy purchases (in this case, increased purchase of natural gas and decreased purchases of electricity, coal and petroleum products) (Figure 2). Ultimately we aggregate these into full-time-equivalent jobs.

Figure 2. Flow Diagram of Employment Impacts (Source: Baer, Brown, and Kim, 2013)



Second Order Impacts. In addition, we consider second order impacts, in which general equilibrium effects such as changes in energy prices due to increased efficiency (so-called "Demand Reduction Induced Price Effects, or DRIPE" and increased natural gas prices propagate through the economy. Second-order impacts derive from redirection of energy bill savings by residential consumers, commercial businesses, and industry (Figure 2). We use the projected changes in energy expenditures from NEMS to calculate second order impacts based on I-O employment coefficients taken from IMPLAN (Impact analysis for PLANning), which is a software and data tool for input-output analyses, describing the sales and purchases relationship between producers and consumers within an economy.

Modeling second-order impacts using NEMS' energy market projections requires a number of strong assumptions. If the scale of efficiency investment is large enough, it will cause economy-wide changes in supply and demand, and thus prices, for energy. This in turn changes the expenditures of various actors. Businesses, whether in the industrial or commercial sector, could pass their energy bill savings on to customers through lower prices, or maintain prices and increase profits or wages, or some combination, and similarly for energy bill increases. As overall energy bill savings recycle through the economy, additional employment impacts are expected when expenditures shift from capital-intensive sectors like utilities to more labor-intensive sectors like services, manufacturing and construction.

As a simplifying assumption, we treat all energy bill savings as direct savings to consumers (assuming that changes in prices, wages, and dividends all eventually accrue to households), and that they are re-spent in direct proportion to the existing distribution of household expenditures. Furthermore, we assume that savings accrue to households in proportion to the existing distribution of household income. While this is unrealistic for a variety of reasons, the employment coefficients for household expenditures by different income brackets vary relatively modestly (about 8% between the highest and lowest). Using this procedure, we calculate a weighted employment multiplier of 15.5 jobs per million dollars of energy bill savings across all sectors in 2009 [5] ; as with all of our multipliers it is "discounted" over time to account for economy-wide productivity increases.[6]

IMPLAN Employment Coefficients. To estimate employment impacts, NEMS' outputs (e.g., additional CHP capacity, sectoral energy consumption, etc.) are combined with I-O employment coefficients (sometimes imprecisely referred to as "multipliers") that are derived from IMPLAN. The employment coefficients were calculated for six components of the CHP technology life-cycle and the associated economy-wide impacts: new construction and equipment installation (which is developed by a bills of goods, discussed below); non-fuel operation and maintenance (O&M); three energy sectors (electric utilities, natural gas, and the coal and petroleum sectors together); and all other sectors affected by energy bill savings in the residential and commercial sectors.

Bills of Goods. To estimate the jobs associated directly with the construction and operation of new facilities, we identify the industrial sectors contributing to the CHP systems using the concept of a "bill of goods". Our bill of goods for CHP systems involves selecting industrial sectors taken from IMPLAN's 440 sectors, the associated employment coefficients also taken from IMPLAN, and a set of estimated weights reflecting each sector's expenditure share. We began with a review of the literature to identify the relevant industrial sectors and their respective proportion of installation costs. We selected ten categories of industrial sectors and estimated the weights for each category. We then conducted an expert survey to validate our estimates. Four of ten experts contacted provided complete responses; two for natural gas-based systems and two for biomass-based systems. Since the fractions are fairly similar, we used the average proportion of all four responses (see Baer, Brown and Kim 2013 for details).

Using this bill of goods and nationally aggregated I-O data, this analysis produced an estimate of 14.5 first-order jobs created per million dollars ($2009) investment in CHP system installation and construction[7]. We also identified employment coefficients for non-fuel O&M sectors of 19.8 jobs per one million dollar of expenditures, electricity sector 5.7, natural gas sector 6.6, and coal and petroleum sector 7.4. The second-order employment impacts that result from redirection of households' spending from energy bill payments to other consumption goods or services are particularly significant, with the second highest employment coefficient, 15.5 jobs per million dollars of investment/expenditure. As a result, the deployment of CHP systems would generate significant employment impacts in the long-term with more labor-intensive O&M and second-order sectoral employment, in addition to the short-term, one-time jobs created during the construction phase. The second-order impacts would be spread across a wide band of economic sectors, roughly proportional to the current distribution of household consumption spending.

Deriving State-Specific Estimates. Employment estimates for the selected four states are produced by a "proportioning" methodology. The methodology is based on the approach used in Brown et al. (2010) that estimates energy consumption and production projections across

[5] We derive this coefficient by assuming that energy-bill savings are proportional to current household income by household income bracket, and that the sectoral spending of energy savings is proportional to current spending. Weighting the employment coefficients according to the sectoral distribution yields the economy-wide average.
[6] We assume that productivity in all sectors increases at a 1.84% annual rate, the economy-wide average for the years 2007-2011.
[7] All figures cited here are for 2012, and are "discounted" over time for productivity increases.

sixteen states located in the South. In this study, we first analyzed the regional CHP capacity and energy demand changes at the Census Region (four) or Division (nine) level, compared to the business-as-usual ("reference") case in NEMS. The Division-level consumption estimates are proportioned by the normalized energy use per capita from 2006 to 2010 with the historical energy consumption by state from the EIA's State Energy Data System (SEDS) and population projections from the U.S. Census Bureau. Then, we derived the annual share of each state relative to Census Division and, using this state specific percentage, we allocated the NEMS energy demand projections to each state. Similarly, for the distribution of CHP capacity, which is also only reported by Census Region in NEMS, historical data from 2004 to 2010 in the ICF database (ICF, 2011) was used to determine an "industrial CHP per capita" parameter for each state. Each state's share of each region's new capacity was calculated by normalizing using this parameter. For instance, California would account for 45 percent of industrial CHP capacity in the West region in 2035 (Table 2).[8]

Table 2: Normalized Industrial CHP Per Capita and State Proportion (in 2035)

(Source of Data: ICF, 2011; U.S. Census Bureau; Authors)

Census Region	State	Industrial CHP Capacity Average: 2004 – 2010 (GW)	Population Average: 2004 – 2010 (million)	Normalized Industrial CHP Capacity per Capita	Regional CHP Capacity in Reference Case in 2035 (GW)	State Share of CHP Capacity Within Region In 2035	Reference Case CHP Capacity in 2035
	US	53.6	301.0	0.178	79.9	100.0%	79.9
West	CA	3.3	36.9	0.084	12.2	44.8%	5.3
Northeast	CT	0.4	3.5	0.103	10.6	3.3%	0.4
	NY	3.7	19.3	0.254		42.8%	4.8
South	TX	8.8	23.5	0.348	43.0	32.2%	13.9

Job estimates by state also require downscaling of energy prices and employment coefficients. To calculate investment and expenditure changes for our first and second-order categories, the state energy demand estimates were applied to energy prices (natural gas, coal prices for residential, commercial, and industrial sectors) that are projected at the level of nine census divisions through 2035 in NEMS, and 22 NERC subregions for electricity. With the data availability, we applied the same energy prices to states located within the same census division.

Employment coefficients are also calculated by state. Using IMPLAN's single state modeling, the first-order employment coefficients of non-fuel O&M, electricity, natural gas, and coal and petroleum sectors were estimated for all states based on a set of industrial sectors and estimated weights in the bills of goods. Finally, state-specific job estimates are calculated with investment changes and employment coefficients. In addition, since the single state modeling in IMPLAN does not capture employment impacts that would be generated in other states from local commodity expenditures in a single state, we add what we call "job leakage" estimates by

[8] Note that the state and national figures for CHP capacity in the 2004-2010 period based on the ICF data are different (about 50% higher nationally) than NEMS data for roughly the same period (2012, see Table 3). The ICF data is used only to calculate population-weighted state proportions, which are then applied to the NEMS calculations of capacity increases compared to the reference case. The source of the discrepancy remains to be identified.

multi-regional modeling in IMPLAN, which provides indirect and induced job impacts on the other eight census divisions and adjacent states in the same census region.[9]

Results

Table 3 shows the installed CHP capacity (in MW) in the US and in our four target states in 2012 and in 2035 in both the reference forecast and the 20% ITC case. These numbers show aggressive CHP growth even in the reference case, as well as a substantial increase of 13.6 GW in the 20% ITC case, which represents a 17% growth of industrial CHP capacity compared to the forecast for 2035. This additional capacity leads to the various changes in prices and demand that drive the net new job creation. Such a policy would fall short of the 2012 executive order goal for 2020. Baer, Brown, and Kim (2013) estimate that 30% ITC could meet the goal in 2023, while a 20% ITC would help achieve only 61% of the executive goal by 2020, as is replicated in this paper.

Table 3. Installed Industrial CHP Capacity (MW) and Increase in Annual Jobs

	CHP Capacity In 2012 (MW)	Reference Case in 2035 (MW)	20% ITC in 2035 (MW)	Change in CHP Capacity (MW)	Increase in Annual Jobs in 2030-2034
US	34,900	79,910	93,490	13,580	33,800
CA	1,800	5,280	6,590	1,310	1,330
CT	112	365	394	29	350
NY	1,490	4,740	5,120	380	940
TX	6,400	13,900	16,100	2,220	4,030

The expanded industrial CHP capacity in turn leads to economy wide changes in energy prices and demand. Electricity price decreases compared to the reference case could benefit residential, commercial, and industrial consumers. Figure 3 shows electricity price changes in each sector in the four census divisions where our sample states are located. In particular, the New England region would experience significant electricity price reductions after 2020 with a 20% ITC. Such price declines can lead to second-order job gains through consumers' energy bill savings.

[9] Note that from a national perspective, this "leakage" of jobs between states is not necessarily a problem, although it does raise potential equity issues about the distribution of costs and benefits. We do not in this paper assess any international "leakage" effects that might be of greater national concern.

Complete estimation of the leakage of jobs between states would require running 51 multi-regional models at the state level for each of the six sectors we define, which would be prohibitively time consuming for a study such as this. As it is, each run of a 12 region model took over three hours. Accordingly, we have simplified for this study by running multi-regional models for only six states (our four target states plus Ohio and Georgia) and estimating the average leakage coefficients on that basis. For the first order jobs, the leakage is small relative to in-state employment coefficients, so the error introduced is likely very small. For second order jobs (modeled by treating energy bill savings as household income increases to the median household, a function provided in IMPLAN), the job leakage is a larger share of total employment per unit spending, and more precise estimates will require more complete multi-regional modeling.

Table 4 shows the average change and the difference in 2035 for electricity prices in each region. In the industrial sector, the New England, Middle Atlantic, West North Central and East South Central regions show electricity price decreases of about 0.5% in 2020-2024 compared to the reference case and would see more significant (up to 2%) decreases in 2030-2034. These electricity price reductions could cause positive second-order job impacts. On the other hand, the remaining regions show no changes or even slight increases in electricity prices in the period of 2020-2024, but all except the Mountain region have price decreases by 2030. The patterns are similar but not identical in the residential and commercial sectors.

Figure 3. Electricity Prices in Each Sector (cents/kWh)
(Source of data: NEMS)

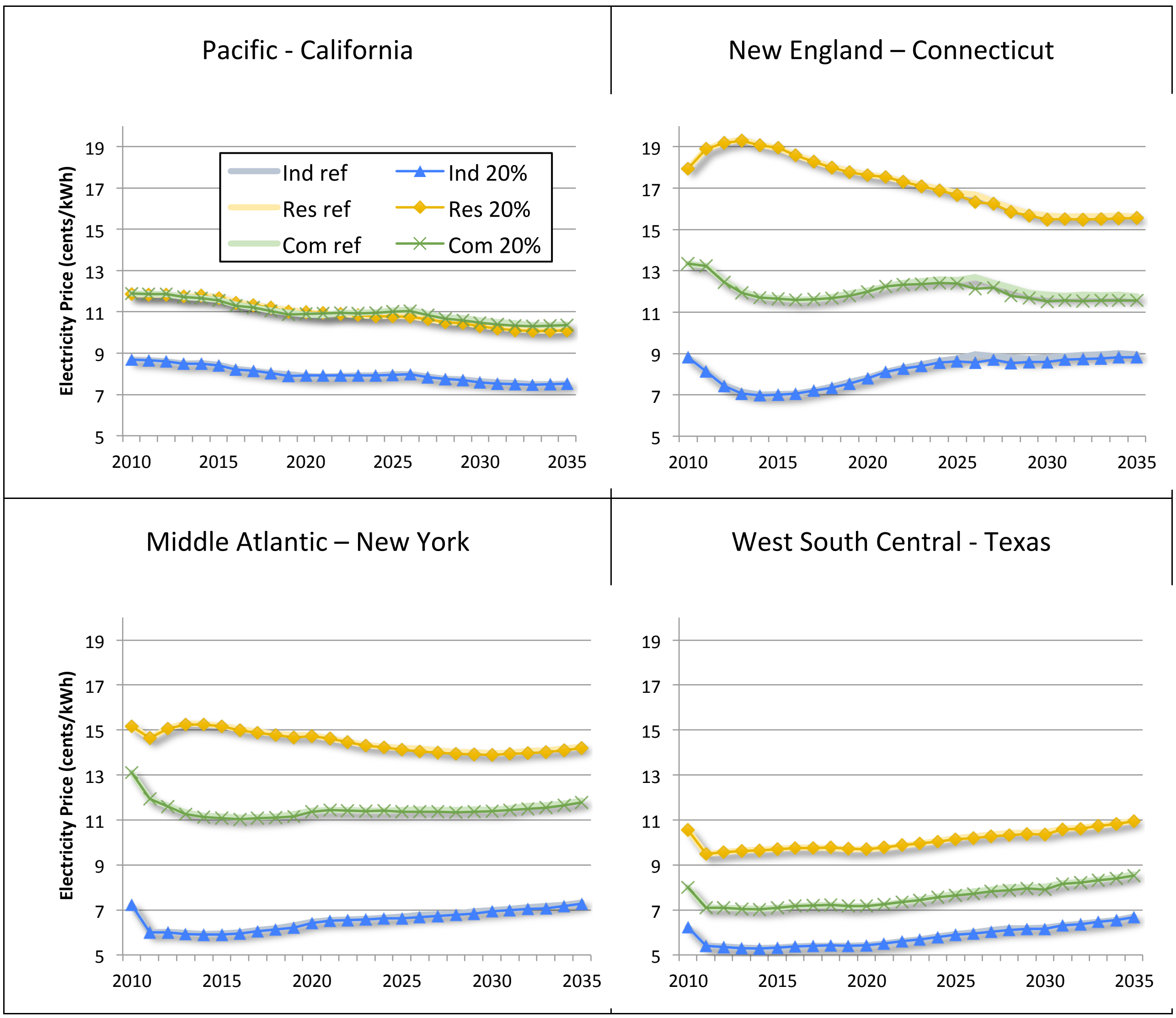


Table 4 also shows the regional comparison of natural gas prices compared to the reference case. In the regions having lower natural gas price with an ITC policy, a CHP system, which is generally fueled by natural gas, could be an attractive option for industrial businesses relying on both thermal and electricity energy together. The average natural gas price decreases in the New England, Middle Atlantic, and West South Central regions in 2030-2034 could be a significant stimulus of CHP deployment in those regions.

Table 4. Regional Electricity and Natural Gas Prices Comparison

Sector	Census Division	State	Average Electricity Price Difference, 2020-2024 (%)	Average Electricity Price Difference, 2030-2034 (%)	Average NG Price Difference, 2020-2024 (%)	Average NG Price Difference, 2030-2034 (%)
Ind	New England	CT	-0.5%	-2.2%	0.2%	-0.1%
	Middle Atlantic	NY	-0.5%	-1.0%	0.2%	-0.3%
	East North Central		0.1%	-0.4%	0.2%	0.2%
	West North Central		-0.4%	-0.8%	0.2%	0.3%
	South Atlantic		0.1%	-0.4%	0.4%	0.4%
	East South Central		-0.5%	-1.3%	0.4%	0.4%
	West South Central	TX	0.0%	-0.4%	0.1%	-0.4%
	Mountain		0.1%	0.0%	0.3%	0.5%
	Pacific	CA	0.2%	-0.6%	0.3%	0.3%
	United States		-0.1%	-0.6%	0.2%	0.1%
Res	New England	CT	-0.3%	-0.9%	0.1%	0.0%
	Middle Atlantic	NY	-0.2%	-0.6%	0.2%	0.0%
	East North Central		0.1%	-0.2%	0.2%	0.4%
	West North Central		-0.4%	-0.7%	0.2%	0.3%
	South Atlantic		0.0%	-0.4%	0.3%	0.3%
	East South Central		-0.3%	-1.2%	0.3%	0.4%
	West South Central	TX	0.0%	-0.4%	0.4%	0.4%
	Mountain		0.1%	0.2%	0.2%	0.4%
	Pacific	CA	0.1%	-0.4%	0.2%	0.3%
	United States		-0.1%	-0.5%	0.2%	0.3%
Com	New England	CT	-0.7%	-2.3%	0.2%	0.0%
	Middle Atlantic	NY	-0.2%	-0.8%	0.3%	0.0%
	East North Central		0.1%	-0.5%	0.3%	0.4%
	West North Central		-0.7%	-1.2%	0.2%	0.4%
	South Atlantic		-0.2%	-0.7%	0.3%	0.4%
	East South Central		-0.9%	-2.3%	0.4%	0.4%
	West South Central	TX	-0.1%	-0.7%	0.5%	0.5%
	Mountain		-0.3%	-0.3%	0.3%	0.5%
	Pacific	CA	0.0%	-0.8%	0.2%	0.4%
	United States		-0.2%	-0.9%	0.3%	0.3%

Jobs Estimation

Figure 4 presents the comprehensive results of the employment analysis of the 20% ITC scenario, comparing the nation and four states. The national estimate shows that the sectors of construction and CHP equipment installation, non-fuel O&M, and natural gas supply and distribution are all sources of job creation. As expected, the number of one-time jobs in CIM slows over time, while the number of jobs in O&M and the natural gas sector increases with CHP capacity accumulation.

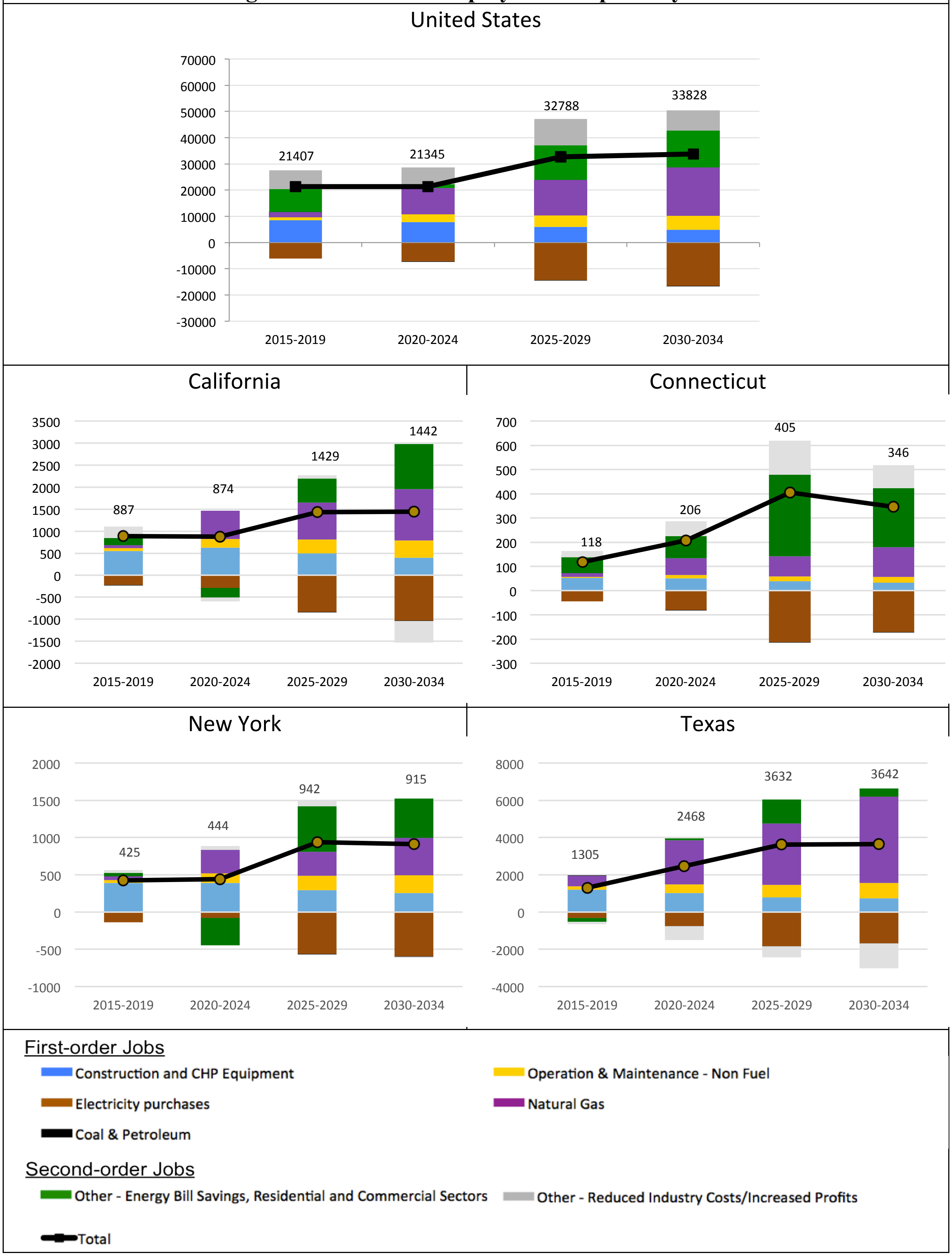
Furthermore, the potential job creation from energy cost savings in the residential and commercial sectors and industrial cost savings would be sources of substantial benefits for the national economy. These second-order impacts broadly track electricity price changes. In general, electricity prices are lower in all sectors in the 20% ITC policy case compared to the reference case, though there is considerable variability over time. These lead to the second-order job gains shown in green and gray in Figure 4.

In contrast, the electric utility sector and the coal and petroleum production and distribution sectors would experience job losses resulting from enhancing industrial energy efficiency as well as switching fuel consumption to natural gas. Overall, however, these effects are much smaller than the job creation in other sectors; as a result, the net annual increase in jobs grows from 21,400 (averaged between 2015 and 2019) to 33,800 (averaged between 2030 and 2034). Among the states we examined, losses in these sectors were about 1/3 to 1/2 of gross job gains in other sectors resulting from expanded CHP.

When looking at state-specific estimates, the employment growth generally tracks the magnitude of CHP growth, with Texas gaining the most and Connecticut the least. The greater proportionate uptick in jobs per GW of expanded CHP in Connecticut and New York (see Table 3) can be understood by examining the sources of job creation. In three of the four states (except Connecticut), jobs from construction, operation and maintenance (not counting fuel) account for roughly half of net jobs growth. New York and Connecticut maintain a similar pattern to the nation, with significant increases in second-order jobs. Industrial CHP users in these states would benefit from reduced costs from purchased electricity, coal and petroleum, and from increased revenues from selling excess power to the grid. These benefits would exceed increased fuel costs on natural gas and O&M costs. On the other hand, California and Texas show reductions in second-order jobs from industrial energy bill changes, compared to the reference case. While industrial consumers who add CHP capacity would benefit from savings in purchased electricity and from sales of power back to the grid, aggregated across the whole industrial sector, expenditures on natural gas are forecast to exceed these savings in California and Texas.

The results in this paper should not be taken as firm predictions since they rely on NEMS projections. For example, as shown in Table 4, NEMS forecasts that natural gas prices fall in the West South Central Region (including Texas) in 2030-2034. This result may simply be an artifact of NEMS complex multi-regional algorithms. More generally, it is strength of NEMS that its detail allows it to generate quite "realistic" projections in terms of inter-annual variability and non-linear responses. However, the particular patterns – e.g. price variations, capacity expansion, etc. – are dependent on many parameters and assumptions that are poorly constrained, especially for longer time horizons. We report period averages to smooth some of the variability, but the results here should be taken as illustrative only, and in need of additional sensitivity analysis.

Figure 4. Estimated Employment Impacts by State and U.S.



Conclusions

A 20% ITC policy is estimated to increase industrial CHP capacity by 13.6 GW in 2035, compared with the reference case forecast. This 20% ITC scenario is used to estimate the employment growth that would result from expanding the use of industrial CHP systems in the US. The addition of 13.6 GW of industrial CHP by 2035 is estimated to produce a net annual increase in jobs growing from 21,400 (in the 2015-2019 timeframe) to 33,800 (averaged between 2030 and 2034), with considerable variation among four sample states, especially in "second order" jobs due to changes in energy bills. Further state-by-state disaggregation and sensitivity to alternative scenarios remains as future research.

Acknowledgement

Funding for this research was provided by Oak Ridge National Laboratory and the Institute of Paper Science and Technology at the Georgia Institute of Technology. Their support and input are greatly appreciated.

References

Baer, P., Brown, M. A., & Kim, G. (2013). The Job Generation Impacts of Expanding Industrial Cogeneration. School of Public Policy, Georgia Institute of Technology, Retrieved from http://www.spp.gatech.edu/aboutus/workingpapers/job-generation-impacts-expanding-industrial-cogeneration

Brown, M. A., P. Baer, M. Cox, and Y.J. Kim. 2013. "Evaluating the Risks of Alternative Energy Policies: A Case Study of Industrial Energy Efficiency," Forthcoming in *Energy Efficiency*.

Brown, M. A., M. Cox, and P. Baer. 2013. "Reviving manufacturing with a federal cogeneration policy." *Energy Policy*. 52 (2013) 264–276.

Chittum, A., & Kaufman, N. (2011). *Challenges Facing Combined Heat and Power Today : A State-by-State Assessment* (Vol. 20045). Retrieved from http://www.uschpa.org/files/public/ie111.pdf

DSIRE. (2013). Database of State Incentives for Renewables and Efficiency. Retrieved from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1

Foster, B., Chittum, A., Hayes, S., Neubauer, M., Nowak, S., Vaidyanathan, S., Rafley, K., et al. (2012). *The 2012 State Energy Efficiency Scorecard*.

ICF International. (2011). Combined Heat and Power Installation Database. *2011*. Retrieved from http://www.eea-inc.com/chpdata/

Molina, M., Neubauer, M., Sciortino, M., Nowak, S., Vaidyanathan, S., Kaufman, N., Chittum, A., et al. (2010). *The 2010 State Energy Efficiency Scorecard* (Vol. 20045).

Sciortino, M., Neubauer, M., Vaidyanathan, S., Chittum, A., Hayes, S., Nowak, S., Molina, M., et al. (2011). *The 2011 State Energy Efficiency Scorecard* (Vol. 20045). Retrieved from http://www.aceee.org/sites/default/files/publications/researchreports/e115.pdf

Sentech Inc. (2010). *Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA*. Washington, D.C.

Shipley, A., Hampson, A., Hedman, B., Garland, P., & Bautista, P. (2008). *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*. Oak Ridge, TN. Retrieved from http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_report_12-08.pdf

The White House. (2012). Executive Order - Accelerating Investment in Industrial Energy Efficiency. *Office of the Press Secretary*. Retrieved from http://www.whitehouse.gov/the-press-office/2012/08/30/executive-order-accelerating-investment-industrial-energy-efficiency

U.S. Energy Information Administration. (2012). *Annual Energy Outlook 2012 with Projections to 2035*.

U.S. Energy Information Administration (EIA). (2012). State Energy Data System (SEDS): 1960-2010. Retrieved from http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US