CONNECTICUT'S CLEAN ENERGY FUTURE

Protecting the Climate • Creating Jobs • Saving Money

LABOR NETWORK FOR SUSTAINABILITY

CT Roundtable on Climate and Jobs

Synapse Energy Economics, Inc.

CONTENTS

INTRODUCTION

This report presents a Clean Energy Future (CEF) plan that realizes Connecticut's official climate protection goal -- reducing greenhouse gas (GHG) emissions 80 percent below the 2001 level by 2050 – while adding more than six thousand jobs and saving money on electricity, heating, and transportation costs.

Connecticut has often been told that doing its share to save the earth's climate will threaten its workers' jobs. "Connecticut's Clean Energy Future: Climate goals and employment benefits" refutes that claim. This report lays out a climate protection plan that will produce more than 6,700 new jobs per year over business as usual projections through 2050. Two-thirds of the jobs created will be in the high-wage construction and manufacturing sectors.

Connecticut's new Governor's Council on Climate Change (GC3) will be developing a new climate change action plan for the state. This report shows that meeting the state's 2050 climate target is feasible if we start now. Indeed, it may be possible to reduce Connecticut's net GHG emissions to zero by 2050.

The report also indicates that Connecticut can use the burgeoning state and national demand for clean energy to create good, stable jobs in a growing climate protection sector: manufacturing jobs, jobs for those who have been marginalized in the current labor market, and jobs for skilled union workers in the construction trades.

This report was prepared by the Labor Network for Sustainability[1] (LNS) and the Connecticut Roundtable on Climate and Jobs[2] with research conducted at Synapse Energy Economics by Dr. Frank Ackerman, Tyler Comings, and Spencer Fields.[3] It is based on the national study "The Clean Energy Future: Protecting the Climate, Creating Jobs, and Saving Money" released October 14, 2015.[4] That study lays out an aggressive strategy for energy efficiency and renewable energy that will:

- Transform the electric system, cutting coal-fired power in half by 2030 and eliminating it by 2050; building no new nuclear plants; and reducing the use of natural gas far below business-as-usual levels.

- Reduce greenhouse gas emissions 86 percent below 1990 levels by 2050, in the sectors analyzed (which

[1] The Labor Network for Sustainability (http://www.labor4sustainabilty.org) was founded in 2009 based on an understanding that long-term sustainability cannot be achieved without environmental protection, economic fairness, and social justice. LNS believes we all need to be able to make a living on a living planet.
[2] The CT Roundtable on Climate and Jobs (http://www.ctclimateandjobs.org/) seeks to strengthen collaboration among the state's labor, environmental, and religious groups in advocating for public policies that protect the climate while creating good-paying local jobs.
[3] Synapse Energy Economics (http://www.synapse-energy.com) is a research and consulting firm specializing in energy, economic, and environmental topics. Since its inception in 1996, Synapse has grown to become a leader in providing rigorous analysis of the electric power sector for public interest and governmental clients.
[4] Labor Network for Sustainability, "The Clean Energy Future: Protecting the Climate, Creating Jobs, and Saving Money" http://www.labor4sustainability.org/wp-content/uploads/2015/10/cleanenergy_10212015_main.pdf

account for three-quarters of US GHG emissions).

• Save money – the cost of electricity, heating, and transportation under this plan is $78 billion less than current projections from now through 2050.

• Create new jobs – more than 500,000 per year over business as usual projections through 2050.

The Clean Energy Future plan does not depend on any new technical breakthroughs to realize these gains, only a continuation of current trends in energy efficiency and renewable energy costs. Most of the additional jobs will be in manufacturing and construction. Such jobs tend to have higher wages and better benefits than average, providing new opportunities for American workers. Because some jobs will be lost in fossil fuel related industries, the report calls for a vigorous program to provide new, high-quality jobs and/or dignified retirement for those affected. The report also advocates deliberate policies to create new opportunities and job pipelines for those groups who have been most excluded from good jobs.

The national study covers the entire electric system, light vehicle transportation (cars and light trucks), space heating and water heating, and waste management. It assumes conversion of all gasoline-powered light vehicles and most space heating and water heating to 100 percent renewable electricity. This strategy achieves three-fourths of the total emissions reduction needed, nationally, to reach the 80 percent by 2050 target. "Connecticut's Clean Energy Future" shows what this plan would mean for Connecticut and what additional measures will make it possible for the state to reach its 2050 climate target.

This report is made possible by the generous support of the Chorus Foundation.

Introduction and conclusion are by the Labor Network for Sustainability and the Connecticut Roundtable on Climate and Jobs; the body of the report is by Synapse Energy Economics. The technical appendix, providing detailed explanation of calculations described in this report, is available at http://synapse-energy.com/CEF_Appendix.

1. CAN CONNECTICUT CUT CARBON EMISSIONS BY 80%?

Connecticut was one of the first states to adopt policies and targets for greenhouse gas reduction. The state's longstanding goal is to achieve 80 percent reduction from 2001 emissions by 2050.[5] This report examines options for reaching that goal, and the resulting impacts on state employment. It is intended as a companion to the national Clean Energy Future study[6], and should be read in conjunction with that study.
The national Clean Energy Future study describes a scenario in which:

- energy efficiency programs are greatly expanded
- a renewable portfolio standard (RPS) requires 70 percent renewable electricity nationwide by 2040
- coal is phased out nationwide – half by 2030, entirely by 2050
- no new nuclear plants are built, while existing ones are phased out after 2030
- electric vehicles replace all gasoline-powered cars and light trucks
- electric heating replaces most fossil-fueled space and water heating

This Clean Energy Future scenario is compared to a Reference Case, assuming no new environmental policies or greenhouse gas reduction initiatives. (The two scenarios make similar assumptions about nuclear power, but diverge on many other issues.) In this report we explore the implications of the Clean Energy Future for Connecticut, and then review available options for greater reduction in state emissions.

Connecticut's role in the national Clean Energy Future does most but not all of what is needed to meet the state's emissions reduction goal for 2050. Since state emissions were 46.25 million tons of CO_2-equivalent in 2001, the target for 2050 is 9.25 million tons. Table 1-1 shows the reduction achieved by the Clean Energy Future, assuming that other emissions and sectors remain unchanged at their 2012 levels. The result would be 15.5 million tons of emissions, a 66 percent reduction from 2001.

[5] Emissions were slightly higher in 2001 than in 1990; the Connecticut goal is equivalent to 79 percent reduction in the state's emissions from the more common base year of 1990.
[6] As described in "The Clean Energy Future", a report from Labor Network for Sustainability, 350.org, and Synapse Energy Economics, available at http://www.labor4sustainability.org/wp-content/uploads/2015/10/cleanenergy_10212015_main.pdf.

CO_2-eq (Million Metric Tonnes)

	2001 Emissions	Clean Energy Future, 2050 or 2012 Actual	Percent Reduction from 2001 Emissions
Power	9.5	4.2	56%
Cars & Light Trucks	11.8	0.3	98%
Residential Heating	8.0	0.8	90%
Commercial Heating	4.0	0.3	92%
Waste	1.5	0.0	100%
Total CEF Sectors	**34.8**	**5.5**	**84%**
Industrial (Non-Electric)	4.4	3.8	12%
Agriculture	0.3	0.3	7%
Residential/Commercial Other	0.8	0.6	20%
Transportation (Except Cars)	6.0	5.3	11%
Total Other Sectors	**11.4**	**10.0**	**12%**
State Total	**46.3**	**15.5**	**66%**

Table 1-1. Connecticut GHG emissions: 2001 and projected 2050

To reach the state target of 9.25 million tons in 2050, another 6.3 million tons of emission reductions are needed. Several feasible initiatives and ongoing trends could contribute to that goal; all of them together would achieve more than 6.3 million tons of reductions, allowing Connecticut to reduce emissions by more than 80 percent by 2050.

We begin with a description of the implications of the Clean Energy Future for Connecticut's energy system and employment, and then turn to the additional options for achieving the final 6.3 million tons of emission reductions.

2. SUN, WIND AND WORKFORCE DEVELOPMENT

a. Energy technologies

The Clean Energy Future will transform Connecticut's energy system by mid-century, building more than 17,000 MW of solar power. Some of this will be in large-scale utility solar facilities, but much of it will be on rooftops and in other small residential and commercial installations. The state will also have 4,000 MW of wind turbines, almost all offshore. These renewable sources of electricity will supply the massive new demand from electric cars and electric heating. At present Connecticut has roughly 2.5 million gasoline-powered cars and light trucks[7] – all of which will be replaced, in the Clean Energy Future, by electric vehicles by 2050. Meanwhile, an active energy efficiency program reduces the demand for electricity by 2 percent every year.

[7] Connecticut Department of Energy and Environmental Protection (DEEP), "2013 Comprehensive Energy Strategy for Connecticut", Appendix D.

The national study contrasts that scenario to a reference case, assuming the continuation of existing trends and policies (prior to the Clean Power Plan), but no new initiatives to promote renewable energy or reduce emissions. Figure 2-1 compares Connecticut's solar power capacity under the two scenarios. By 2050, the state has 17,400 MW of solar capacity in the Clean Energy Future, versus 2,500 MW in the Reference Case.

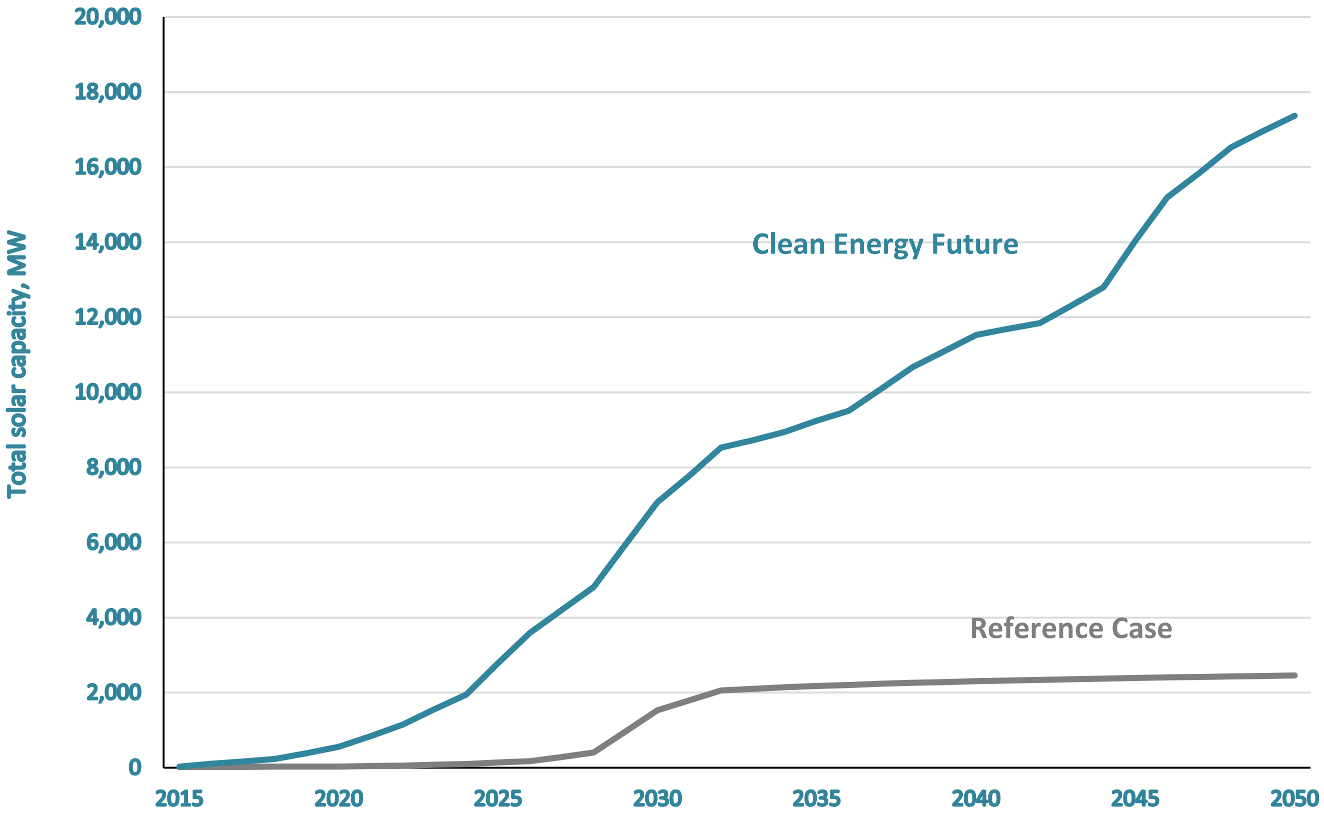

Figure 2-1. Solar power capacity in Connecticut under two scenarios.

A similar comparison for wind power appears in Figure 2-2. By 2050 Connecticut has 4,000 MW of wind power in the Clean Energy Future, versus 1,200 MW in the Reference Case. For both solar and wind power, the Reference Case includes growth far beyond today's levels – but the Clean Energy Future involves installing several times as much renewable energy capacity by 2050. The Clean Energy Future capacity in 2050, in both solar and wind power, is a little more than half the state's technical potential as estimated by the National Renewable Energy Laboratory (NREL).[8]

[8] According to NREL, Connecticut has the technical potential for 7 GW (7,000 MW) of offshore wind, in the near-offshore areas of Long Island Sound, almost no onshore wind potential, and 29 GW of photovoltaic capacity. See Anthony Lopez et al. (2012), "U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis", http://www.nrel.gov/docs/fy12osti/51946.pdf.

In the short run there may be opposition to offshore wind development, just as there is opposition to a national commitment to phase out coal. In the long or even medium run, such opposition will have to be overcome in order to achieve a clean energy future. Looking at a wind turbine does not actually harm anyone, unlike, say, breathing near a coal plant. And the view of Long Island Sound with wind turbines in the distance looks distinctly better than a shoreline inundated by rising sea levels if climate change continues unchecked. Connecticut cannot necessarily count on building renewable capacity in nearby states, since these states, too, will have ambitious targets and building plans of their own.

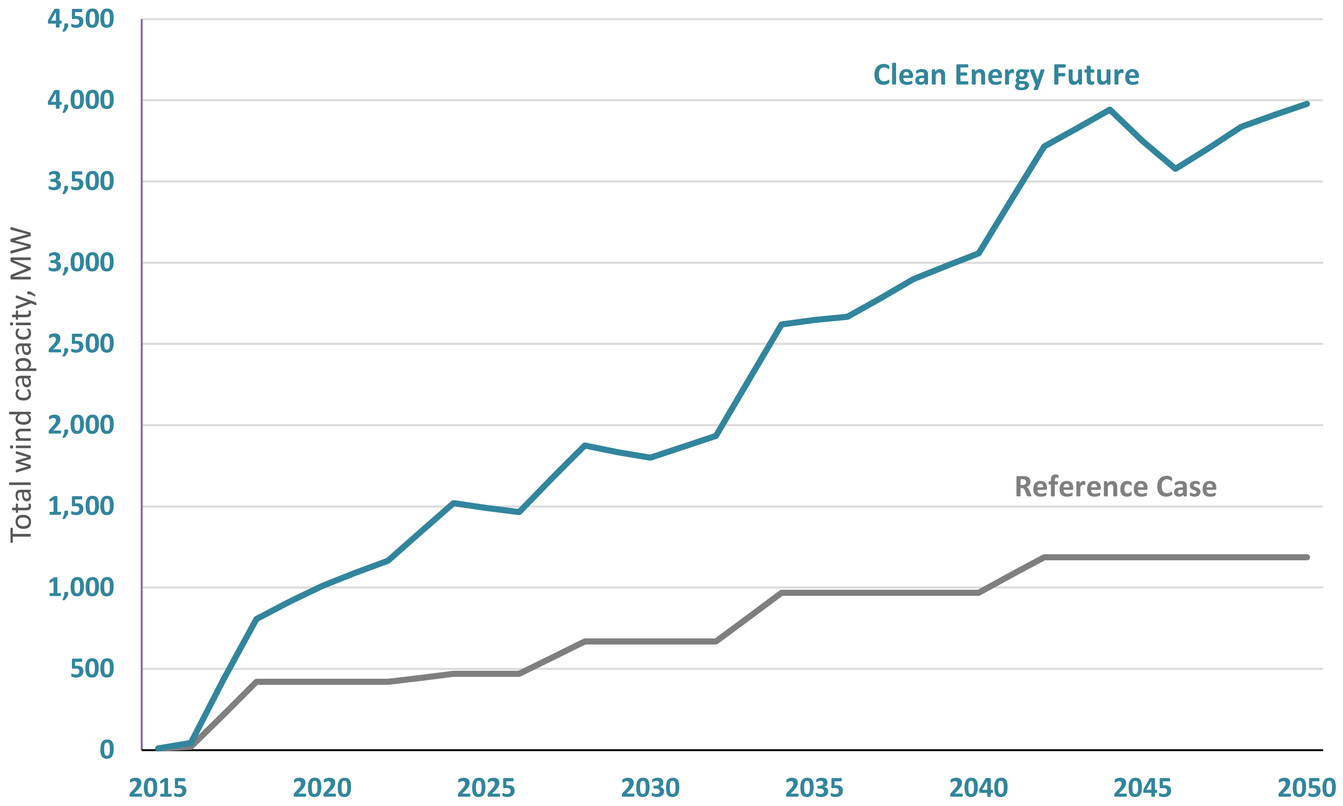

Figure 2-2. Wind power capacity in Connecticut under two scenarios.

Note: the dip in capacity in the 2040s results from accidents of timing of old unit retirements and new unit construction in the model, and does not represent an economically significant change.

Conventional power generation is little changed between the two scenarios. Bridgeport Harbor, the state's only coal plant, shuts down in 2020 in the Clean Energy Future, versus 2026 in the Reference Case. (In other words, it is too expensive to keep operating for long, even under the "no new environmental policies" assumptions of the Reference Case.) Both scenarios assume that nuclear plants will shut down 60 years after they began commercial operation, which means retirement in 2035 for Millstone 2 and 2046 for Millstone 3. Natural gas capacity in Connecticut is identical in the two scenarios, declining by 11 percent from 2015 to 2050, as shown in Figure 2-3.

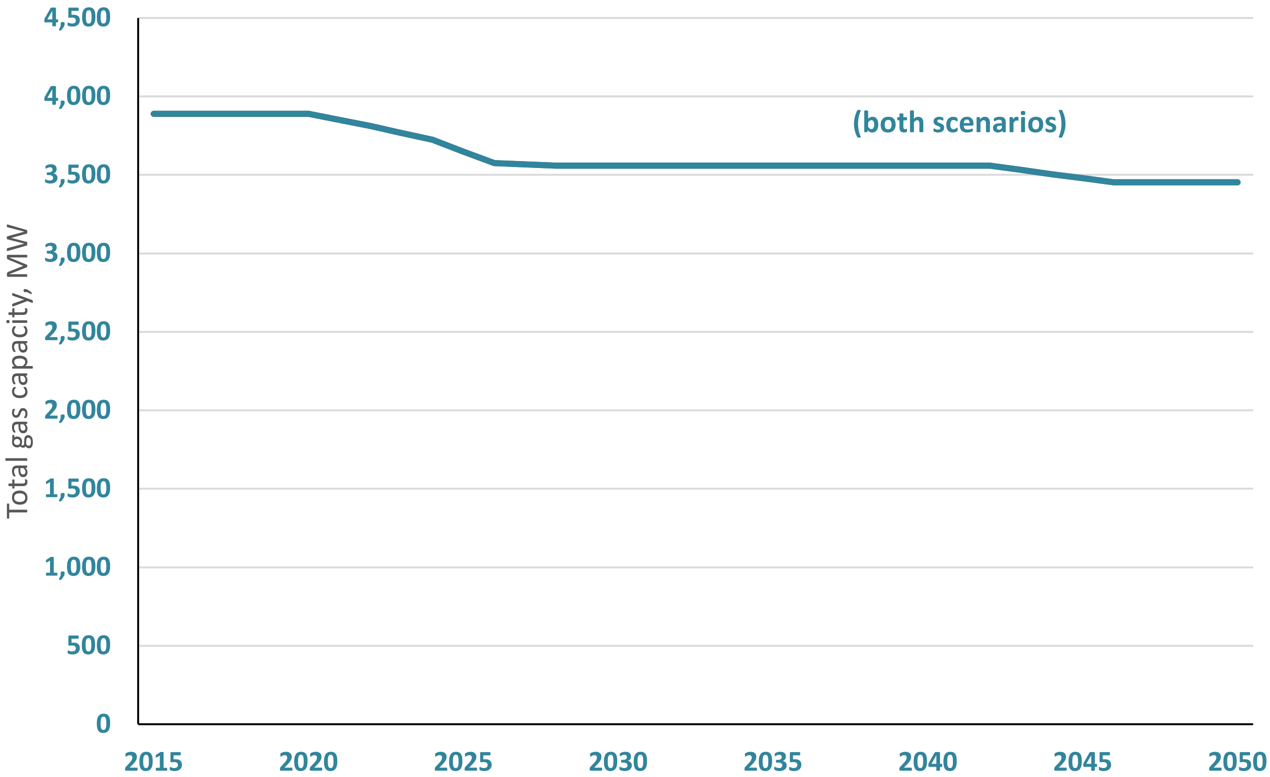

Figure 2-3. Natural gas-fired generating capacity in Connecticut under two scenarios.

With little change in the level of conventional generation, the huge expansion of wind and solar power is needed to serve the new electric vehicle and heating loads. The Clean Energy Future involves investment in energy efficiency, reducing the demand for electricity, but this is more than balanced by the expansion of electric vehicle and heating markets – accomplishing a massive substitution of renewable electricity for gasoline, fuel oil and natural gas.

A similar pace of renewable capacity expansion will be required throughout the country to create the Clean Energy Future. Indeed, the ambitious expansion plans projected for Connecticut, as described here, include less than 1 percent of the wind capacity and less than 2 percent of the solar capacity needed nationwide in 2050.

b. Employment in the Clean Energy Future

The Clean Energy Future creates an annual average of 6,713 more jobs in Connecticut, compared to the Reference Case. This is about 0.4 percent of total employment in the state in 2012, as shown in Table 2-1. About two-thirds of the new jobs are in construction and manufacturing, the industries with the greatest percentage increases in employment.

Among the economic sectors shown in the table, only utilities are projected to have net job losses under the

Clean Energy Future. The net loss of 360 utility jobs combines the loss of about 660 jobs in conventional power plants, offset by a gain of 300 jobs in operations and maintenance of wind and solar power (all job figures are annual averages, 2016-2050).

	2012 Employment	New Jobs in Clean Energy Future	
		Annual Average	As % of 2012
Total, All Industries	1,775,238	6,713	0.38%
Above Average Growth			
Construction	51,579	1,680	3.3%
Manufacturing	165,197	2,671	1.6%
Real Estate, Rental and Leasing	18,743	144	0.8%
Wholesale Trade	63,289	437	0.7%
Management of Companies and Enterprises	30,566	187	0.6%
Agriculture, Forestry, and Fishing	5,048	28	0.6%
Finance and Insurance	114,572	506	0.4%
Below Average Growth			
Information	31,206	82	0.3%
Health Care and Social Assistance	276,277	574	0.2%
Arts, Entertainment, and Recreation	41,331	83	0.2%
Retail Trade	182,169	240	0.1%
Accommodation and Food Services	117,737	97	0.1%
Administration, Waste Management, and Remediation	83,842	69	0.1%
Professional, Scientific, and Technical Services	89,474	72	0.1%
Transportation and Warehousing	43,325	29	0.1%
Education	182,634	109	0.1%
Government (Except Education)	85,201	35	0.0%
All Other	72,751	30	0.0%
Job Losses			
Utilities	5,930	-360	-6.1%

Table 2-1. New jobs in Connecticut in the Clean Energy Future - all sectors

Source: 2012 employment from Connecticut Department of Labor projections, available at http://www1.ctdol.state.ct.us/lmi/projections.asp.

From National to State Employment Estimates

Estimates of Connecticut employment from the Clean Energy Future were derived from the national study estimates.[9] The national study used NREL's ReEDS model to project expansion plans for the electric system, and then applied the IMPLAN model to calculate the resulting employment impacts. IMPLAN reports three categories of employment: direct jobs (such as construction workers who install wind turbines); indirect jobs created at suppliers (such as the steel mill workers who make steel for the turbine blades); and induced jobs (created when the construction workers and steel mill workers spend their paychecks, stimulating other industries).

For direct jobs, we used the actual location of existing and projected new energy facilities, as reported by the ReEDS model. Direct jobs are created in Connecticut to construct and operate energy facilities located in the state, as estimated by ReEDS. For indirect and induced jobs, we assumed that jobs in each industry would be distributed in proportion to current employment. For example, Connecticut currently has about 2 percent of national employment in fabricated metal products manufacturing. So 2 percent of all new indirect and induced jobs in fabricated metal products are assumed to be located in Connecticut – regardless of where the demand for these products originates.

[9] See http://synapse-energy.com/sites/default/files/Clean-Energy-Future-15-054.pdf for the national study and http://synapse-energy.com/CEF_Appendix for the technical appendix.

More detail on manufacturing is shown in Table 2-2. Almost all (88%) of the new manufacturing jobs are in five sectors: electrical equipment, primary metals, fabricated metal products, machinery, and transportation equipment. Among the branches of manufacturing shown in the table, none is projected to have net job losses, although some have near-zero gains. Electrical equipment and appliances, by far the fastest-growing sector, benefits from the surge in demand for new energy-efficient lighting and appliances, as well as new equipment needed by electric utilities as they adapt to renewable energy.

	2012 Employment	New Jobs in Clean Energy Future	
		Annual Average	As % of 2012
Total, Manufacturing	165,197	2,671	1.6%
Above Average Growth			
Electrical Equipment, Appliances, and Components	9,840	739	7.5%
Primary Metals	3,829	101	2.6%
Fabricated Metal Products	29,215	760	2.6%
Machinery	14,599	369	2.5%
Nonmetallic Mineral Products	2,242	36	1.6%
Plastics and Rubber Products	5,828	90	1.5%
Transportation Equipment	42,071	395	0.9%
Paper Manufacturing	3,564	26	0.7%
Textiles and Textile Products	1,808	13	0.7%
Computers and Electronics	13,034	55	0.4%
Below Average Growth			
Chemicals	11,345	38	0.3%
Printing	5,489	16	0.3%
Wood Products	1,162	3	0.3%
Beverages and Tobacco Products	907	2	0.2%
Food Products	7,044	15	0.2%
Furniture	2,385	4	0.2%
Miscellaneous Manufacturing	10,473	9	0.1%

Table 2-2. New jobs in Connecticut in the Clean Energy Future – manufacturing

Note: "Above average" and "below average" categories are based on the average for all sectors, from Table 2-1.

The Clean Energy Future will help create good jobs in Connecticut, but it is not enough, in the state or the country as a whole, to transform the economy and end unemployment. It is a positive contribution, which could be one of several parts of a broader jobs strategy for the twenty-first century.

Current policy discussion often includes large, sometimes misleading estimates of the job creation potential of clean energy. How could our agenda call for installing more than 17,000 MW of solar power in Connecticut, yet create less than 2,000 new jobs in construction? Recall that the solar capacity is a cumulative total; the Clean Energy Future calls for a long-term annual average of 500 MW of solar installation, versus 70 MW in the Reference Case.

Moreover, we assume faster technological progress and lower prices for solar power in the Clean Energy Future. As a result, solar panel installation creates about 3 job-years per MW in the Clean Energy Future, versus 6 job-year per MW in the Reference Case.[10] These numbers together imply that the annual average employment of construction workers installing solar panels is a little over 400 in the Reference Case, versus about 1,500 in the Clean Energy Future. The difference between the number of solar installers in the two scenarios, a little more than 1,000 jobs, accounts for the majority of the 1,680 new construction jobs due to the Clean Energy Future, as shown in Table 2-1.

3. OPTIONS FOR DEEPER REDUCTIONS

As noted above, the Clean Energy Future achieves most but not all of the reduction in greenhouse gas emissions required to reach the state's 2050 target. Assuming that all Clean Energy Future targets are reached, and all other sectors have the same emissions in 2050 as in 2012, Table 1-1 shows that Connecticut emissions would be reduced from 46.3 to 15.5 million metric tonnes (MMT) of CO_2-eq. Additional reductions of 6.3 MMT are required to reach the 2050 target. There are multiple options for additional reductions, which offer more than one path for the final stage of the journey.

a. Forest sequestration

Plants grow by absorbing carbon dioxide from the atmosphere, potentially offsetting emissions in other sectors. For this reason, an estimate of net forest growth is often included in greenhouse gas inventories as a negative emission, or offset to emissions. EPA's national greenhouse gas inventory includes a substantial estimate for forest carbon sequestration.

Connecticut's 2009 greenhouse gas inventory accurately observed that "the available data [on forest sequestration] is of lower quality than comparable data on fuel consumption or industrial processes", and noted that a change in methodology and reporting in the 1990s caused a large shift in estimates of the effects of forests on greenhouse gases. To avoid such problems, Connecticut inventories have omitted all forestry impacts.

Nonetheless, others have analyzed forest carbon sequestration in the state. A study by Acadia Center (formerly Environment Northeast) estimates that Connecticut forests sequestered 3.6 million tons of carbon dioxide in 2010.[11] More recently, detailed academic research on southern New England forests has found net annual sequestration in Connecticut of 9 – 11 MMT.[12] If these rates of absorption of carbon dioxide

[10] These estimates can be compared to a study of firms installing solar panels in Connecticut in 2014, a year of extremely rapid expansion. The study found that seven small firms created from 2 to 11 jobs per MW of solar capacity installed that year. See "Preparing Connecticut's Solar Workforce for Growth" (2015), Yale University, Table 1, p.33.
[11] Environment Northeast (2010), "Climate Vision 2020", measured from graph on p.25.
[12] Linda Powers Tomasso and Mark Leighton (2014), "The Impact of Land Use Change for Greenhouse Gas Inventories and State-Level Climate Mediation Policy: A GIS Methodology Applied to Connecticut", *Journal of Environmental Protection* 5, 1572-1587.

continue, they will offset more than half of the remaining target for reduction, at the Acadia study's rate, or more than the entire remaining target, at the academic study rate. The longstanding goal of preserving 21 percent of the state's area as open space will contribute to forest preservation and carbon sequestration, as well as providing other amenities such as recreation.[13]

Thus the decision about whether to include forest sequestration, and if so, which estimate to use, could eliminate much or all of the remaining emission reduction target.

b. Fuel cells and combined heat and power

Connecticut's electric system today is heavily dependent on natural gas-fired generation. Under the Clean Energy Future, that dependency is reduced but not eliminated; the projected power system emissions of 4.2 MMT in 2050 (see Table 1-1) reflect the continuing use of natural gas, alongside a vastly expanded renewable energy sector. Conventional power plants burn gas to generate electricity, but make little or no use of the waste heat that is a byproduct of generation. Combined heat and power (CHP) technologies provide an opportunity to use natural gas more efficiently, jointly producing and selling both electricity and heat. CHP is particularly appropriate when – as in Connecticut – power plants can be located close to industrial, commercial or institutional customers that can use the heat for space heating, water heating, or industrial process heat.

The 2005 Climate Change Action Plan estimated that a requirement to obtain 8 percent of the state's electricity from "clean CHP" facilities could save 1.4 MMT of CO_2 emissions by 2020. And there is no need to stop at 8 percent; even more could be done. Another study projects that realizing the state's total potential for CHP and district heating could save 8.1 MMT of annual emissions.[14]

Promotion of CHP provides an opportunity to showcase, and support, Connecticut's leading position in the fuel cell industry. According to industry sources, Connecticut has 28 percent of the US workforce, and 8 percent of the global workforce, in the fuel cell industry.[15] Fuel cells are one of several technologies for CHP; they have near-zero emissions of conventional pollutants, and can be built in a modular fashion, avoiding zoning restrictions on other types of power plants.[16] Among states, Connecticut is second only to California in stationary fuel cell capacity. California's 45 MW of fuel cell capacity is largely a result of a state policy, the California Self-Generation Incentive Program, showing that this is an area where state government makes a difference.[17]

Connecticut currently has 41 stationary fuel cells with a total capacity of 29 MW.[18] Half of that capacity is at the Dominion facility in Bridgeport; the rest is distributed around the state, primarily in 200 – 400 kw units at major industries, commercial and office buildings, schools and hospitals. The industry recommends a target

[13] See the discussion of land preservation in DEEP (2014), "Taking Action on Climate Change: 2014 Progress Report", p.24.

[14] NESCAUM (2010).

[15] "Connecticut Hydrogen and Fuel Cell Coalition: 2014 Annual Report", http://www.chfcc.org.

[16] US EPA (2015), "Catalog of CHP Technologies, Section 6. Technology Characterization – Fuel Cells", http://www3.epa.gov/chp/documents/catalog_chptech_6.pdf.

[17] *Ibid.*, p. 6-3.

[18] Norhteast Electrochemical Energy Storage Cluster (2015), "Connecticut Hydrogen and Fuel Cell Development Plan", http://neesc.org/publications/2015_roadmaps/.

of 131 to 175 MW of fuel cell electric generation by 2025.[19] Much more could be done, of course, by 2050. In addition to efficient use of natural gas and near-zero pollution levels, fuel cell CHP facilities provide benefits of resilience: they can be configured to be able to run independently of the grid. This was valuable during Hurricane Irene in 2011 and Superstorm Sandy in 2012, when fuel cells helped keep communications functioning during major power outages.

c. Smart growth and expanded transit

Connecticut's high density and heavy commuter traffic mean that traffic-reducing, transit-promoting alternatives will have multiple benefits, cutting down on congestion and other forms of pollution as well as reducing GHG emissions. Increased provision of mass transit is helpful today in the highest-density, most heavily travelled corridors; it will be even more helpful in the long run if future development follows transit-centered "smart growth" patterns. The 2005 Climate Change Action Plan projected that doubling transit usage by 2020 would save 0.5 MMT of greenhouse gases per year. Another study estimated that promotion of smart growth patterns and the associated increase in transit and reduction in driving would save about 0.7 MMT by 2020, with much greater savings in the long run.[20]

These savings are, in a sense, double-counting savings from the Clean Energy Future, which projects elimination of gasoline-powered light vehicles by 2050. Yet they are still worth pursuing, since they may provide GHG reduction benefits much sooner than the introduction of electric vehicles in the Clean Energy Future, and they also provide additional benefits of more livable communities and reduced congestion, relieving the pressure for expensive investments in road and highway expansion. Expanded transit options could reduce the need for electric vehicles, allowing a somewhat slower pace of development of renewable energy.

d. Capturing HFCs

One high-priority option for reducing greenhouse gases results from the unintended consequences of solving a different environmental problem. The threat of depletion of the ozone layer, recognized in the 1980s and addressed by the Montreal Protocol, led to the replacement, beginning in the 1990s, of ozone-depleting substances, particularly in refrigeration and air conditioning. The first round of replacements involved chemicals such as hydrofluorocarbons (HFCs), which are potent greenhouse gases (they have very high global warming potential – "high GWP"). As a result, there is a substantial climate benefit to capturing these gases when refrigeration and air conditioning units are repaired, refilled, or discarded. Newer chemicals are being developed that can avoid damaging either the ozone layer or the climate.[21] One study estimates that capturing half of the ozone-depleting substances, such as refrigerants, released in Connecticut would save 1.5 MMT of CO_2-eq annually.[22] A DEEP survey of GHG reduction strategies identified a set of measures related to high-GWP refrigerants that would avoid 1.7 – 1.9 MMT annually.[23] (These

[19] *Ibid.*

[20] NESCAUM (2010).

[21] See the discussion of this issue in the national Clean Energy Future report.

[22] NESCAUM (2010).

[23] CT DEEP (2010), "CT GHG Recommended Actions and Potential GHG Reduction Strategies".

emissions are counted as industrial emissions in the state greenhouse gas inventory, regardless of which sector actually emits them.)

e. Fuel efficiency in trucks and heavy equipment

Transportation is the leading source of greenhouse gas emissions in Connecticut; a significant share of those emissions come from non-auto transport, such as trucks and buses. One study projected that under business as usual, on-road freight transport will account for 2.3 MMT of CO_2-eq in Connecticut in 2020, and 2.8 MMT in 2040; if growth continues at that pace, on-road freight (trucking) emissions will reach 3.1 MMT in 2050.[24] Promotion of fuel efficiency in trucks is important – and entirely practical. It is primarily a matter for federal policy, although there are steps that a state can take as well.

The heaviest trucks on the road, Class 8 tractor-trailers, account for most trucking emissions. Federal fuel efficiency standards for trucks have just begun to take effect; Phase 1 standards require 6 percent improvement in fuel efficiency by the 2017 model year.[25] Phase 2 standards, which have been proposed but not adopted, will require an additional 18 to 24 percent improvement beyond 2017 levels by 2027.[26]

A number of innovative companies, spurred by the Department of Energy's "Supertruck" program, have already demonstrated that much more can be done, even with existing technology. Tractor-trailers on the road average about 6 mpg today, and business-as-usual projections from the Energy Information Administration suggest little better than 8 mpg in 2050. In contrast, new, ultra-aerodynamic truck prototypes have already achieved 10 – 13 mpg under actual highway conditions.

If the average tractor-trailer on the road reaches this level of energy efficiency by 2050, and comparable improvements are made in other classes of trucks, then business-as-usual trucking emissions could be cut by one-third. For Connecticut, with a projected 3.1 MMT of CO_2 emissions from trucking in 2050, the savings would be 1.0 MMT. Even more than that could conceivably be done to improve fuel economy and lower truck emissions, with another 35 years of technological development.

It is not possible for Connecticut to set its own fuel economy or truck emission standards. However, there are steps that can be taken at the state level to reduce truck emissions. Heavy trucks often spend several hours per day idling at truck stops, in order to keep air conditioning and other services running. A study for DEEP recommended strengthening Connecticut's prohibition on idling, and establishing a heavy-duty vehicle inspection and maintenance program, as the most promising short- and medium-term strategies for heavy vehicle emission reduction.[27]

[24] 2020 and 2040 estimates are from a 2013 study for DEEP, "Development of a Strategic Plan for Reducing Emissions Associated with Freight Movement in Connecticut."

[25] EPA and NHTSA (2011), "Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles", p.5-7. (A wide range of standards are developed for different classes of trucks; this is the CO_2 emission reduction required from Class 8 truck engines under Phase 1.)

[26] EPA and NHTSA (2015), "Proposed Rulemaking for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engings and Vehicles-Phase 2", page ES-13.

[27] "Development of a Strategic Plan for Reducing Emissions Associated with Freight Movement in Connecticut," cited above.

Greater short-run gains may come from measures aimed at cleaning up the oldest and dirtiest diesel engines in the state. The 2005 Climate Change Action Plan estimated that retrofitting 75 percent of existing on-road and off-road diesel engines (a category that includes construction equipment as well as trucks and buses) to reduce particulate emissions could save 2.4 MMT of CO_2-eq, largely through reduction of black carbon (soot), a powerful greenhouse gas.[28] Another study, assuming that much less could be done, produced a much lower estimate of savings from a smaller package of similar measures.[29] Reduction of particulate emissions, which would be achieved by these initiatives, has important health benefits in addition to its contribution to climate mitigation.

f. Summary of other options

The options for emission reduction beyond the Clean Energy Future, discussed in this section, are summarized in Table 3-1. The low-end estimate of the potential shown here, adding the lower values for each option, is greater than the 6.3 MMT target for additional reductions needed to meet the state target in 2050. The high-end estimate of the options in the table is enough, in combination with the Clean Energy Future, to reduce net Connecticut emissions to roughly zero in 2050.[30]

Measure	**Emission reduction, 2050** (MMT CO_2-eq)	**Explanation**	**Source**
Forest sequestration	3.6 – 9.0	Forest carbon sequestration is counted as an offset to emissions in the federal, but not Connecticut, GHG inventory.	Environment Northeast 2010; Tomasso & Leighton 2014
Promote CHP (and fuel cells)	1.4	Proposal to require 8% of electricity from CHP – even more could be done	CCAP 2005
Smart growth, expanded mass transit	0.7	Estimate for 2020; cumulative effects grow larger. This double-counts emission reduction in Clean Energy Future – but works faster, and has other benefits.	NESCAUM 2010
Capture HFCs	1.5 – 1.9	Capture high-GWP substances such as HFCs, often from old refrigeration or air conditioning equipment	DEEP 2010, NESCAUM 2010
Truck fuel efficiency	1.0	Assumes average truck on the road in 2050 matches recent fuel-efficient prototypes	Authors' calculations
Large trucks – quick fixes	0.4 – 0.5	Aerodynamic retrofits, reduce idling at truck stops, better tire inflation	DEEP 2010, NESCAUM 2010
Retrofit off-road diesels	0.1 – 2.4	Reduction in particulate emissions, including black carbon	CCAP 2005, NESCAUM 2010
TOTAL	**8.0 – 16.2**	**Includes all above measures except smart growth and transit** *(see discussion of double-counting in section 3.c)*	

Table 3-1. Summary of additional options for emission reduction
Source: See text, sections 3.a – 3.e.

28 "Connecticut Climate Change Action Plan" (2005), Measure 9.

29 NESCAUM (2010).

30 The possibility of net zero emissions depends on the size of the forest sequestration offset.

CONCLUSION: WHY WAIT?

Connecticut has long been committed to doing its share to reduce the greenhouse gas (GHG) emissions that threaten the future of humanity. But many wonder just how that can be done and worry that it will threaten their jobs.

Connecticut's Clean Energy Future, as laid out in this report, represents a practical plan to reduce GHG emissions 80 percent by 2050 – the minimum reduction that climate scientists say can limit climate catastrophe and the target required by Connecticut law. It shows that climate protection will produce at least six thousand more jobs than continuing on a fossil fuel "business as usual" pathway, most of them well-paid, family-supporting jobs in manufacturing and construction.

Connecticut has a long history of bipartisan leadership on climate protection:

1990 - CT passed first-in-the-nation state global warming legislation to reduce carbon emissions.

2002 - Gov. Rowland established the Governor's Steering Committee on Climate Change.

2005 - A Climate Change Action Plan (CCAP) laid out 55 detailed recommendations for achieving the state's greenhouse gas (GHG) emissions reduction goals for 2010 and 2020.

2008 - The Global Warming Solutions Act, signed by Gov. Jodi Rell, incorporated the CCAP's goals into state law and also established the more ambitious goal of an 80% reduction in GHG emissions by 2050.

2015 – Gov. Dannel Malloy established the new Governor's Council on Climate Change and charged it with developing a plan to reach the 2050 goal. No other state has such a plan.

The Clean Energy Future plan provides a floor, not a ceiling, for what can be accomplished. It shows that meeting our climate goals will create more jobs. But we can, and indeed should, do more. For example, mass transit can be expanded far faster. GHG reduction targets can be met earlier. GHG emissions can be reduced to near zero. We can achieve such goals just by accelerating and adjusting the same basic plan.

Connecticut can achieve many of its other goals while implementing an aggressive climate protection plan, but to realize these "co-benefits" it will need policies designed to do so:

- The Clean Energy Future will entail the creation of more than six thousand new jobs. But there is no guarantee that they will be good jobs. Indeed, depending on other economic trends, spending on climate protection could increase inequality and provide increasingly insecure, contingent work. We can design our climate protection plan to maximize the number of good, secure, permanent jobs with education, training, and advancement. We can institutionalize economic planning that will provide sustained, orderly development for an expanding climate protection sector and prevent boom-and-bust cycles that are devastating for workers and employers. Since the deterioration in the quality of jobs is directly related to the reduction in the size and bargaining power of labor unions, reinforcing the right of workers to organize and bargain collectively should be an explicit part of public policy for climate protection.

- Because a few hundred jobs will be lost in utilities – less than one-tenth as many as will be added in the rest of the economy – we need a vigorous program to provide new, high-quality jobs and/or dignified retirement for workers in those industries. State energy policy should require that utilities make new jobs available to any workers adversely affected by climate protection; that utilities fund a program to assist any workers they do not reemploy; and that utilities negotiate transition plans with their employees.

- The Clean Energy Future plan opens up new opportunities to counter racial, gender, geographic and other inequalities. Climate protection programs should include job pathways, strong affirmative action provisions, and local hiring requirements for those groups that have been most excluded from good jobs in the past.

- The Clean Energy Future allows for a far more local and less top-down energy system. To evolve in that direction, Connecticut can steadily increase its Renewable Portfolio Standard for in-state electricity generation. It can end the prohibition on shared solar generation. It can rapidly modernize its electrical grid to support decentralized, distributed generation. It can provide encouragement for local economic initiatives, ranging from energy coops to locally- and community-based enterprises. Indeed, climate protection provides an opportunity for re-visioning Connecticut.

The new Governor's Council on Climate Change (GC3) will be developing a new climate change action plan for the state of Connecticut. "Connecticut's Clean Energy Future" affirms that reaching the state's goal of reducing GHGs 80% below 2001 levels by 2050 is not only feasible, but will also increase jobs and strengthen our economy in the process. The GC3 can go boldly forward to project a vision of a Connecticut that is safe for the global climate. It can establish a practical plan to realize that vision. And it can design that plan so that it also helps achieve the employment and other goals that are so important to the future of our state.

Such a plan may require some corrections in our current course. Indeed, we will need to evaluate everything we do that affects our future in light of it. We will need to ask, how can Connecticut encourage manufacturing of fuel cells, electric transportation equipment, and other products needed for the clean energy future? Should we be widening highways or should we be investing in electric vehicle fleets and public transit? Should we be expanding natural gas infrastructure and importing energy from distant sources or should we concentrate our investment on job-creating renewable generation right here in our state?

The Clean Energy Future represents a pathway away from climate destruction that is also far better for workers and consumers than our current pathway based on fossil fuels. Connecticut can start moving now to gain its share of the benefits of the Clean Energy Future. What are we waiting for?