Scenarios

Executive Summary

The overall objective of this chapter is to 1) assess the different options that exist to meet the county's 2050 emission goals, and 2) make recommendations for the most important steps that need to be taken for these goals to be met. In previous chapters, we have assessed the different factors, both natural resources and otherwise, that could aid the county in its goal. The findings of the previous reports are summarized in Table 1 and Figure 1 as they relate to the model's parameters and constraints.

Table 1. Local generation potential

Energy Sources		Electricity		Number of Household Powered
		Installed Capacity (MW)	Annual Energy Output (GWh)	
Solar Photovoltaics	Residential - Urban	14.6	16.2	2,068
	Residential - Rural	98.2	108.9	13,899
	Commercial	119.2	132.2	16,873
	Industrial	19	21	2,680
	Public and Community Services	72.7	80.7	10,300
	PV Farms	1,887.7	2,093.4	267,186
	Subtotal	2,211.4	2,452.4	313,006
Wind Energy	Small-Scale	38.6	39.9	5,093
	Medium-Scale	295.5	649.7	82,923
	Large-Scale	120.0	302.2	38,571
	Subtotal	454.1	991.8	126,586
Micro-Hydro		88.5	725.7	92,623
Local Electricity Generation Potential		2,754.0	4,169.9	532,214
Energy Sources		Heating (MMBtu/yr)		Number of Household Heated
Biomass Energy		4,518,037		49,649
Deep Geothermal Energy		Unlimited		N/A

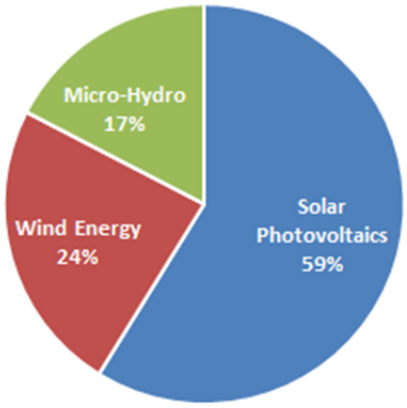

Figure 1. Local renewable electricity generation potential: 4,169.9 GWh annual electricity output

Our model separated energy demand into three different sectors: Heating, Transportation and Electricity.

- Heating: Providing energy for thermal comfort in the winter seasons. Heating demand was accounted for in MMBtus (Million Metric British Thermal Units) and only greenhouse gas (GHG) emissions resulting from providing heating with direct fossil fuel combustion were considered. The emissions associated with electricity-powered heating, such as using a ground- or air-source heat pump, were accounted for in the Electricity section.
- Transportation: Allowing members of the community to get from place to place and goods to be transported within the county. Transportation demand was recorded in Vehicle Miles Traveled (VMT) and only emissions that resulted from directly burning fossil fuel were considered for the transportation emission profile of the county. Emissions associated with VMT from electric vehicles, for instance, were accounted for in the Electricity section.
- Electricity: Electrical energy provided for the electric devices, lighting, heating, transportation, and other electrical needs in the county. Electricity demand was accounted for in terms of kWh. We considered only the demand side so inefficiencies in the production and transmission of electricity were not considered.

Each of these areas is discussed in greater detail in the coming sections. Once the logic behind the choices made in the formulation of the model is explained, several scenarios are presented that demonstrate the effects of each sector on the emissions in the county based. After public input is received and considered recommendations will be made regarding options for the path forward and initial steps that could be taken towards the county's goal.

1. Model Design

1.1 Estimating Growth Rates

In developing scenarios for the Roadmap, the growth rates of future energy demand in the County must be considered. Energy demand is evaluated in three sectors, namely heating, transportation and electricity.

Electricity demand growth was based on published materials. The EIA has estimated a .7% annual growth rate for electricity demand since 2000 [1]. Extrapolating that for the 42 years in between 2008 and 2050, resulted in a projected 34.04% growth from 2008 to 2050.

Heating demand growth was somewhat harder to estimate. In the end, heating demand was estimated to grow at a rate similar to the rate of growth of households in the county. The household growth rate is projected to be .6783% annually [2] until 2050 based on recent history. Expanding this into a 42 year growth rate (2008-2050), results in heating demand for the county approximately 32.83% larger than it was in 2008. This was applied to the heating demand for the entire county including Cornell.

Transportation demand growth rates were the most difficult to determine. Transportation needs had grown very steadily from 1990 to 2007, but experienced a decrease at that point. They stayed constant for the start of the 2010s, but have started increasing again in 2014. This increase coincides with a decrease in gasoline prices. Utilizing the EPA Motor Vehicle Emissions Simulator (MOVES) model, VMT in the county is projected to grow by 34.2% over 2008-2050 [9]. This rate is larger than the projected growth of the county's population over the same period, i.e. 23.96% [3], based on the model's expectation of continued growth in a dispersed geographical pattern consistent with recent historical trends.

1.2 Model Setting and Constraints

Heating Heating demand from Cornell in 2008 was met by steam generated in its Central Energy Plant. Cornell will likely need to utilize resources similar to those needed in the rest of the county as alternative energy sources, i.e. biomass, heat pumps, and/or deep geothermal, if it plans to reduce its GHG emissions from heating. Heating demand from Cornell was included in the county's overall demand for heating in 2008. Cornell's annual heating demand was ~1,200,000 thousand pounds of steam [8], which is equivalent to 1,442,400 MMbtu. It is assumed that the consumption level will grow at the same rate as the rest of the county's heating demand. For energy supplies to meet the heating demand of the county several sources were considered. Natural gas was the primary thermal energy source in the county in 2008, accounting for 81.7% of total demand. For modeling purposes, we assumed that natural gas is the only form of fossil fuels used for meeting heating demand in the county in 2050. In other words, fuel oil and propane will be totally replaced.

Three other options were considered as feasible options for meeting the heating demand, i.e. ground-source heat pumps (GSHP), air-source heat pumps (ASHP), and biomass combustion. For the purposes of our model, GSHPs and ASHPs create no direct emission but do require an input of electricity. It should be noted that although the coefficient of performance (COP) for a GSHP can reach 5.0-7.2 and an ASHP COP can reach 2.2-3.8 under the right conditions, typically the values are a little bit lower. We chose 3.5 for GSHP and 2.5 for ASHP in our model to make conservative estimates. The biomass resources considered in the Roadmap would be agricultural and/or forest biomass harvested sustainably within the county, i.e., at a rate below the rate of carbon sequestration from plant growth. It is assumed that biomass heating is carbon neutral on an annual basis and there are no net emissions for the purposes of our model.

Finally, the potential for reducing the heating demand was also evaluated. This would include improving building energy efficiency, i.e. insulation and air sealing, and other similar improvements. From the energy Demand-Side Management chapter, we found that primary energy consumed for heating accounts for ~65% and ~71% of total energy consumption, respectively, for commercial and residential buildings. Assuming that building performance improvements apply equally to reducing both heating energy and electricity use of a building, a weighted average of 69% by floor area of the two types of buildings was estimated to be the percent of overall efficiency improvements from building energy retrofits that would apply to thermal energy demand. Therefore the potential of non-electrical efficiency improvements is 69% × 4,605,870 MMBtu/yr = 3,178,050 MMBtu/yr, in which 4,605,870 MMBtu/yr is the total energy saving potential from building energy retrofits within one year. In addition, for the purposes of accounting, energy efficiency was treated as an emission-free method of heating.

Table 2 concisely lists all of our heating sources and assumptions. The "Maximum Deployment Percentage" tells the maximum percentage of demand that can be supplied by this source of energy. The "Energy Potential" tells the actual amount of energy that this source of energy can theoretically supply based on the assessments in the previous chapters. Natural gas is assumed to be limited to 2008 levels.

Table 2. The county's sources of heating, their technical constraints, and effects on the rest of the county.

Heating Source	Maximum Deployment Percentage	Energy Potential (MMBtu/yr)	Emission Factor ($MTCO_2e$/MMBtu)	Electricity Demand ($MMBtu_{electricity}/MMBtu_{heat}$)
Natural Gas	100.0%	4,257,152 (2008 usage level)	0.053187436	N/A

Ground-Source Heat Pump	100.0%	N/A	0*	3.5 (typical COP of a GSHP)
Air-Source Heat Pump	100.0%	N/A	0*	2.5 (typical COP of an ASHP)
Biomass	51.1%	4,518,037	0	N/A
Non-Electrical Efficiency Improvements	36.0%	3,178,050	N/A	N/A

*Accounted for in electricity

Transportation When considering transportation, there were three main types of vehicles to consider, i.e. diesel-powered, gasoline-powered and electricity-powered. Vehicles can also fall into three general classes: light-duty (LD), medium-duty (MD), and heavy-duty (HD), where because of different size and functions, the transportation demand for MD and HD vehicles could not be provided by LD vehicles. In 2009, ~3.4% of VMT was by MD vehicles and ~1.3% of VMT was by HD vehicles [4]. It was assumed that the proportions hold true for 2008.

Table 3. Necessary vehicle mileages

	2009	Fraction
LD	654,726,656	95.3%
MD	23,109,397	3.4%
HD	8,874,046	1.3%

In the model only LD vehicles are deemed to be replaceable by electric vehicles (LD EVs) based on current technology. VMT by LD gasoline vehicles in 2008, i.e. 95.3%, could be met by LD gasoline vehicles and/or LD EVs.

Additionally, the National Highway Traffic Safety Administration (NHTSA) and Environmental Protection Agency (EPA) have mandated that the Corporate Average Fuel Economy (CAFÉ) for LD vehicles (including passenger cars, SUVs, vans, and pickup/light trucks) reaches at least 54.5 miles per gallon (MPG) by model year (MY) 2025 [16]. The penetration of hybrid electric vehicles, plug-in hybrid electric vehicles, and battery electric vehicles by MY 2025, as included by NHTSA and EPA in their compliance demonstration, are 5%, 0% and 2% respectively. Since the fleet of EVs considered is minimal, it was reasonable to assume that by 2025 the average MPG of new LD gasoline vehicles within the county will comply with this standard and that the average for all vehicles would achieve this level by 2050. It was also assumed that the average fuel economy of LD vehicles remain unchanged between 2025-2050, as at present there are no document to support a better CAFÉ performance during that period.

For MD and HD vehicles, we assumed that they would meet the proposed Phase 2 MD/HD vehicle fuel efficiency and greenhouse gas (GHG) standards [5]. The kWh/mile for EVs are the best practices at present carried on to 2050. It was assumed that the technologies do not change in order to make conservative estimates.

As with the Transportation section, we also considered options that allowed people to avoid driving cars at all. Transportation Demand Management (TDM) includes increases in carpooling, walking, bicycling, and using public transportation. For the purposes of accounting, these were treated as

emission-free sources of VMT. The maximum deployment percentage of LD TDM is half of that for LD VMT, i.e. 47.6%, as it was assumed that at most 50% of LD VMT could be reduced by TDM. Table 4 below concisely lists all of our transportation options and assumptions. The definitions for "Maximum Deployment Percentage" and "Energy Potential" are the same as those defined above in the Heating section.

Table 4. The county's sources of transportation, their technical constraints, and effects on the rest of the county.

Vehicle Type	Maximum Deployment Percentage	Energy Potential (VMT)	Emission Factor (lb CO_2e/gallon)	Miles per Gallon	Electricity Demand [kWh/mile]
LD EV	95.3%	95.3% of the 2050 usage level	0	N/A	0.3
HD Diesel	1.3%	N/A	22.6	10.0	N/A
MD Diesel	3.4%	N/A	22.6	30.0	N/A
LD Gasoline	95.3%	N/A	19.8	54.5	N/A
TDM	47.6%	47.6% of the 2050 usage level	N/A	N/A	N/A

Electricity When considering the electricity demand for the county, increases in electricity demand due to changes in the transportation and heating sectors had to be added to direct electricity demand from the county..

In 2008, the vast majority of the electricity in the county came from the grid. In our 2050 scenarios, we also considered the introduction of local generating capacity such as solar, wind, and micro-hydro. All three of these are intermittent resources. Because of this, we do not rely solely on one resource but on a balanced profile in which resources are mutually complementary over seasonal variations of their availability. Also, for our model, we assumed that any loss of 1 MMBtu of dispatchable capacity would require 2 MMBtu of renewable capacity. This design factor was intended to ensure system reliability by considering inefficiencies in energy storage and in meeting inflexible demand under extreme weather with intermittent resources.

The 2015 New York State Energy Plan sets a 2030 goal of generating 50% of the state's electricity from renewable energy, including large-scale hydropower. Our model assumes that the rest 50% will be generated by natural gas units running on highly efficient combined cycle technology, due in part to the uncertainty of nuclear power with most plant licenses expiring during the coming decades. This gives a grid carbon intensity of approximately 0.44 lb/kWh [6] [7], or 0.000199581 MTCO2e/kWh. The model does not assume further progress by 2050 than what is provided in the State Energy Plan.

As with the above two sections, we also accounted for the potential reduction in demand due to increases in use of energy efficient devices, lighting, electric vehicles, and heat pumps, separate from the energy efficiency achieved by improving building energy performance in the heating sector. Based on the analysis above in the heating section, 1 - 69% = 31% of the total energy saving from building energy retrofits can be achieved by non-heating efficiency improvements. Therefore the potential of non-heating efficiency improvements is 31% × 4,605,870 MMBtu/yr = 1,427,820 MMBtu/yr or 418 GWh, in which 4,605,870 MMBtu/yr is the total energy saving from building energy retrofits within one year. Table 5 below explains our options for electricity production and assumptions. The definition for "Energy Potential" is the same as that defined above in the Heating section.

Table 5. The county's sources of heating, their technical constraints, and effects on the rest of the county.

Electricity Source	Energy Potential (GWh)	Carbon Intensity ($MTCO_2e/kWh$)	Design Factor
Grid	N/A	0.000199581	N/A
Solar	2,452	0	2
Wind	992	0	2
Micro-Hydro	726	0	2
Non-Heating Efficiency Improvements	418	N/A	N/A

1.3 Model Validation

In order to demonstrate the effectiveness of our model, we used it to reproduce the emission levels of the county in 2008. The year 2008 was chosen because it is the year where the most complete data set was available, including a GHG Emissions Inventory created by the county and it is the base year for the County's 80% emission reduction goal. Parameters in the model setting were derived from the Inventory as shown in Table 6.

Table 6. Model settings derived from the 2008 CO_2e inventory

Growth Percent	0.00%
$MTCO_2e/MMBtu$ Heating Fuel Mix Usage	0.056298193
Average MPG for MD and HD Diesel	4.8
MPG for LD Gasoline	17.4
$MTCO_2e/kWh$ Electricity Usage	0.000316378

Table 7. 2008 model validation

Sector	Energy Sources	Percent of Demand	Percent of Potential	Energy/VMT Supply*	CO2e Emissions (MTCO2e)	Contribution to the Emissions Reduction
Heating (MMBtu)	Natural Gas	100%	122%	5,208,990	293,257	0%
	Ground-Source Heat Pump	0%	N/A	0	0	
	Air-Source Heat Pump	0%	N/A	0	0	
	Biomass	0%	0%	0	0	
	Non-Electrical Efficiency	0%	0%	0	0	
	Subtotal	100%	N/A	5,208,990	293,257	
Transportation (Mile)	Electric Light-Duty	0%	0%	0	0	100%
	Electric Medium-Duty	0%	0%	0	0	
	Electric Heavy-Duty	0%	0%	0	0	
	Diesel Heavy-Duty	1%	N/A	8,927,231	19,245	
	Diesel Medium-Duty	3%	N/A	23,348,143	50,333	
	Gasoline Medium-Duty	0%	N/A	0	0	
	Gasoline Light-Duty	95%	N/A	654,434,724	337,813	
	Transportation Demand Management	0%	0%	0	0	
	Subtotal	100%	N/A	686,710,099	407,392	
Electricity (kWh)	Grid	100%	N/A	779,312,378	246,557	0%
	Solar	0%	0%	0	0	
	Wind	0%	0%	0	0	
	Micro-Hydro	0%	0%	0	0	
	Non-Heating/Cooling/Transportation Efficiency	0%	0%	0	0	
	Subtotal	100%	N/A	779,312,378	246,557	
Cornell Power Generation/Heating Demand		N/A	N/A	N/A	139,833	0%
Others (CO2e emissions from waste, agricultural activities, and Groton electricity purchase)		N/A	N/A	N/A	85,801	0%
Total CO2e Emissions (MTCO2e)		1,172,840				
Percent Change		-0.01%				

As shown in Table 7, we can reproduce the 2008 CO_2e emissions inventory within ~.01% of the inventory value. With an error margin that slim, our model has been validated and can be used to adequately predict the emissions within the county given changing variables.

2. Scenarios and Discussion

The model built serves as a tool for us to define probable scenarios under which the county's 80% GHG reduction goal could be reached. We formulated four scenarios: 1) Business as usual, 2) Mixed, 3) All electric, and 4) Maintaining half of current natural gas. The rationale behind each scenario is explained below. In addition, in order to inform further decision-making the following information is provided: details about the percent of demand met by each energy source in the three sectors; the percent of energy potential reached by each source of supply; the energy supply and CO2e emissions from each energy source; total and each sector's' contribution to the emissions reduction; and opportunities and challenges influencing the actions to be taken under each scenario.

One principle that needs to be mentioned up front is that when choosing which approach to take to reduce GHG emissions, energy efficiency (EE) is given priority. EE is considered as "low-hanging fruit" because it has had wide application in the county for decades and energy savings from EE

improvements are usually significant. Deep-geothermal is not discussed in the scenario development as there is currently no proven technology in Northeast US so its potential is hard to quantify.

Scenario A - Business As Usual (BAU)

Scenario A is formulated to show what the county's carbon footprint would be if no particular actions other than those already implemented or planned by 2015 are taken to reduce GHG emissions.. Business as usual indicates that as in 2008, in 2050 80% of heating energy will come from natural gas, 95% of transportation will be served by gasoline light duty vehicles, and 76% of electricity will be provided by the power grid.

It, however, incorporates the current development and planning of renewable electricity, which includes the solar farms developed by Cornell, TC3 and the City of Ithaca, as well as the Black Oak Wind Farm. The capacity of PV systems installed, under construction, and/or planned in the county as of February 2015 is 20.8 MW, which is ~7% of the potential of solar electricity in the county. The capacity of the Black Oak Wind Farm is 11.9 MW. This is ~11% of the potential of wind electricity in the county.

Foreseeable improvements in energy efficiency for new buildings are also included. In the 2015 International Energy Conservation Code [13][14], heating EUI at 3.4 Btu/hr per sq. ft. is considered low energy for both residential and commercial buildings. The heating EUI of residential buildings in the county is ~7.0 Btu/hr per sq. ft. and for commercial buildings, it is ~16.3 Btu/hr per sq. ft. Weighted averaging the two heating EUIs by their respective floor area, the current heating EUI of buildings in general in the county is ~9.6 Btu/hr per sq. ft. If it is assumed that the 3.4 Btu/hr per sq. ft. is the best practice now and that all new constructions built in the county between 2008 and 2050 will reach this level, c savings of heating energy in new buildings can reach ~65%. The growth rate of new households in the county is forecasted to be 32.83% between 2008 and 2050. Assuming that existing buildings under the business as usual scenario do not. make efficiency improvement and reduce their energy use the overall heating energy usage may be reduced by ~20% from the baseline projection in 2050.

The transportation sector includes the increased MPGs of gasoline- and diesel-powered vehicles as specified in the previous section of model design. The electricity sector includes the efficiency improvements in electric appliances and lighting systems. On ENERGY STAR's website, their labeled appliances [15] use 10%-25% less energy than conventional models and their CFL/LED light bulbs use 70%-90% less energy than fluorescent ones. Assuming this is the best practice now and all electric appliances and lighting systems will reach these energy efficiency levels by 2050, a conservative value of 10% reduction in energy consumption was chosen.

Table 8. Scenario A - business as usual

Sector	Energy Sources	Percent of Demand	Percent of Potential	Energy/VMT Supply*	CO2e Emissions (MTCO2e)	Contribution to the Emissions Reduction
Heating (MMBtu) (incl.Cornell heating demand)	Natural Gas	80%	166%	7,066,437	375,846	15%
	Ground-Source Heat Pump	0%	N/A	0	0	
	Air-Source Heat Pump	0%	N/A	0	0	
	Biomass	0%	0%	0	0	
	Non-Electrical Efficiency	20%	56%	1,766,609	0	
	Subtotal	100%	N/A	8,833,046	375,846	
Transportation (Mile)	Electric Light-Duty	0%	0%	0	0	62%
	Electric Medium-Duty	0%	0%	0	0	
	Electric Heavy-Duty	0%	0%	0	0	
	Diesel Heavy-Duty	1%	N/A	11,980,344	12,281	
	Diesel Medium-Duty	3%	N/A	31,333,208	10,707	
	Gasoline Medium-Duty	0%	N/A	0	0	
	Gasoline Light-Duty	95%	N/A	878,251,400	144,947	
	Transportation Demand Management	0%	0%	0	0	
	Subtotal	100%	N/A	921,564,953	167,935	
Electricity (kWh)	Grid	76%	N/A	796,604,572	158,987	23%
	Solar	9%	7%	182,594,386	0	
	Wind	5%	11%	104,459,031	0	
	Micro-Hydro	0%	0%	0	0	
	Non-Heating/Cooling/Transportation Efficiency	10%	25%	104,459,031	0	
	Subtotal	100%	N/A	1,188,117,020	158,987	
Others (CO2e emissions from waste, agricultural activities, and Groton electricity purchase)		N/A	N/A	N/A	85,801	0%
Total CO2e Emissions (MTCO2e)		788,569				
Percent Change		-33%				

Given the trends of change above, Scenario A indicates that without particular actions other than those already implemented or planned by the Federal and State governments and the county to reduce GHG emissions, by 2050 GHG emissions will still be 33% less than the 2008 level in spite of the growth in energy demand. This level of reduction, however, is far less than the county's 80% goal. Therefore, more aggressive scenarios need to be created to provide guidance to actions that should be taken by the county.

Scenario B - Mixed

The Mixed scenario was created following the principles below:

1) Maintain the amount of natural gas used by the industrial sector at its 2008 level, i.e. 10% of the total amount of natural gas used in the county in 2008. This recognizes that alternatives to natural gas use may not be as easily achieved in the industrial sector and maintains gas use equivalent to 2008 industrial use levels.
2) Non-electrical building energy efficiency and transportation demand management are raised to 50% of potential respectively, and non-heating efficiency is raised to 80%. 50% of potential is the approximate cutoff for the employment of energy efficiency potential in our scenario development, yet as is estimated above in the BAU scenario, it's reasonable to save ~80% of energy from the improvement of lighting systems and electric appliances.

3) Balance the percent of heating demand met by ground source heat pumps (GSHP) and air source heat pumps (ASHP). Both GSHPs and ASHPs have their advantages and disadvantages. For example, a GSHP has a higher COP but also requires higher capital cost to install. So it's hard to predict which heating source will have a higher rate of deployment in 2050.
4) Balance the percent of transportation demand met by gasoline light-duty vehicles and electric light-duty vehicles. This is to assume that 50% of the gasoline light-duty vehicles employed in 2008 are to be replaced by electric light-duty vehicles in 2050. Electric medium-duty and heavy-duty vehicles are not considered as viable replacements to their diesel counterparts in 2050 because there is no proven technology at this point to allow for the conversion.
5) Micro-hydro is controlled at ~20% of its potential. As is analyzed in the Micro-hydro chapter, there are many restrictions to the employment of micro-hydro in the county, so a modest percent of potential is assumed.
6) Scenario B controls biomass and renewable electricity at ~53% of their potential.

Table 9. Scenario B - Mixed

Sector	Energy Sources	Percent of Demand	Percent of Potential	Energy/VMT Supply*	CO2e Emissions (MTCO2e)	Contribution to the Emissions Reduction
Heating (MMBtu) (incl.Cornell heating demand)	Natural Gas	5%	10%	419,570	22,316	44%
	Ground-Source Heat Pump	25%	N/A	2,213,561	0	
	Air-Source Heat Pump	25%	N/A	2,213,561	0	
	Biomass	27%	53%	2,396,405	0	
	Non-Electrical Efficiency	18%	50%	1,589,948	0	
	Subtotal	100%	N/A	8,833,046	22,316	
Transportation (Mile)	Electric Light-Duty	36%	38%	329,459,471	0	35%
	Electric Medium-Duty	0%	0%	0	0	
	Electric Heavy-Duty	0%	0%	0	0	
	Diesel Heavy-Duty	1%	N/A	11,980,344	12,281	
	Diesel Medium-Duty	3%	N/A	31,333,208	10,707	
	Gasoline Medium-Duty	0%	N/A	0	0	
	Gasoline Light-Duty	36%	N/A	329,459,471	54,374	
	Transportation Demand Management	24%	50%	219,332,459	0	
	Subtotal	100%	N/A	921,564,953	77,362	
Electricity (kWh)	Grid	16%	N/A	254,433,077	50,780	21%
	Solar	41%	53%	1,300,995,881	0	
	Wind	17%	53%	525,880,873	0	
	Micro-Hydro	5%	20%	145,255,292	0	
	Non-Heating/Cooling/Transportation Efficiency	21%	80%	334,937,908	0	
	Subtotal	100%	N/A	2,561,503,031	50,780	
Others (CO2e emissions from waste, agricultural activities, and Groton electricity purchase)		N/A	N/A	N/A	85,801	0%
Total CO2e Emissions (MTCO2e)		236,259				
Percent Change		-80%				

The major challenge in the Mixed scenario is not technology. This is because all the renewable energy sources are employed at moderate levels and their use in the county have been successfully demonstrated. It is human behavior to accept these new energy sources that is hard to change. Another challenge is the uncertainty regarding whether the natural gas supply can be maintained in the county given the reduced demand. If 4.8% of demand does not support maintaining natural gas supply, it may not be available or a more cost-effective form of a distributed supply chain like current propane delivery could be required.

Scenario C - All Electric

In the all electric scenario, all three sectors rely on electricity as their source of energy. Heating demand is primarily met by GSHP and ASHP in equal amounts. In the transportation sector, 72% of VMT, i.e. the proportion left from TDM and from those served by diesel medium-duty and heavy-duty vehicles, are met by electric light-duty vehicles. In the electricity sector, only 32% of electricity can be extracted from the power grid to control the total GHG emissions.

Table 10. Scenario C- all electric

Sector	Energy Sources	Percent of Demand	Percent of Potential	Energy/VMT Supply*	CO2e Emissions (MTCO2e)	Contribution to the Emissions Reduction
Heating (MMBtu) (incl.Cornell heating demand)	Natural Gas	0%	0%	0	0	46%
	Ground-Source Heat Pump	41%	N/A	3,621,549	0	
	Air-Source Heat Pump	41%	N/A	3,621,549	0	
	Biomass	0%	0%	0	0	
	Non-Electrical Efficiency	18%	50%	1,589,948	0	
	Subtotal	100%	N/A	8,833,046	0	
Transportation (Mile)	Electric Light-Duty	72%	75%	658,918,941	0	41%
	Electric Medium-Duty	0%	0%	0	0	
	Electric Heavy-Duty	0%	0%	0	0	
	Diesel Heavy-Duty	1%	N/A	11,980,344	12,281	
	Diesel Medium-Duty	3%	N/A	31,333,208	10,707	
	Gasoline Medium-Duty	0%	N/A	0	0	
	Gasoline Light-Duty	0%	N/A	0	0	
	Transportation Demand Management	24%	50%	219,332,459	0	
	Subtotal	100%	N/A	921,564,953	22,988	
Electricity (kWh)	Grid	32%	N/A	623,332,397	124,405	13%
	Solar	33%	53%	1,300,715,451	0	
	Wind	14%	53%	526,118,985	0	
	Micro-Hydro	4%	20%	145,431,264	0	
	Non-Heating/Cooling/Transportation Efficiency	17%	80%	334,802,991	0	
	Subtotal	100%	N/A	2,930,401,089	124,405	
Others (CO2e emissions from waste, agricultural activities, and Groton electricity purchase)		N/A	N/A	N/A	85,801	0%
Total CO2e Emissions (MTCO2e)		233,194				
Percent Change		-80%				

One prominent feature of the all electric scenario is the complete transition to light-duty electric vehicles. This would require infrastructure such as electric vehicle charging stations to support this transition. And upgrading the current transmission grid may be required to support a higher capacity and more diverse electricity supply.

Scenario D - Maintaining Half of Current Natural Gas (NG)

If we apply a 50% limitation on natural gas usage, all of the demand for light-duty VMT has to be served by electric light-duty vehicles if the 80% goal is to be reached, even with 100% renewable electricity. To limit biomass, solar, and wind energy at ~53% of potential, both non-electrical efficiency and non-heating efficiency must achieve 80% of potential.

Table 11. Scenario D - maintaining half of current natural gas

Sector	Energy Sources	Percent of Demand	Percent of Potential	Energy/VMT Supply*	CO2e Emissions (MTCO2e)	Contribution to the Emissions Reduction
Heating (MMBtu) (incl.Cornell heating demand)	Natural Gas	24%	50%	2,119,931	112,754	34%
	Ground-Source Heat Pump	10%	N/A	883,305	0	
	Air-Source Heat Pump	10%	N/A	883,305	0	
	Biomass	27%	53%	2,411,422	0	
	Non-Electrical Efficiency	29%	80%	2,535,084	0	
	Subtotal	100%	N/A	8,833,046	112,754	
Transportation (Mile)	Electric Light-Duty	72%	75%	658,918,941	0	41%
	Electric Medium-Duty	0%	0%	0	0	
	Electric Heavy-Duty	0%	0%	0	0	
	Diesel Heavy-Duty	1%	N/A	11,980,344	12,281	
	Diesel Medium-Duty	3%	N/A	31,333,208	10,707	
	Gasoline Medium-Duty	0%	N/A	0	0	
	Gasoline Light-Duty	0%	N/A	0	0	
	Transportation Demand Management	24%	50%	219,332,459	0	
	Subtotal	100%	N/A	921,564,953	22,988	
Electricity (kWh)	Grid	5%	N/A	69,677,889	13,906	25%
	Solar	47%	53%	1,309,944,307	0	
	Wind	19%	53%	529,551,954	0	
	Micro-Hydro	5%	19%	139,355,777	0	
	Non-Heating/Cooling/Transportation Efficiency	24%	80%	334,453,866	0	
	Subtotal	100%	N/A	2,382,983,792	13,906	
Others (CO2e emissions from waste, agricultural activities, and Groton electricity purchase)		N/A	N/A	N/A	85,801	0%
Total CO2e Emissions (MTCO2e)		235,449				
Percent Change		-80%				

Challenges that scenario D faces include both those for scenario B and scenario C, i.e. behavior change and infrastructure. More detailed strategies are needed to solve the problems.

3. Conclusions

Table 12. Comparison of scenarios

Scenarios	A - BAU	B - Mixed	C - All Electric	D - Reduced NG
% of Current Natural Gas Usage Level	166%	10%	0%	50%
% of Heating from local Renewables (including heat pump systems and biomass)	0%	77%	82%	47%
% of Energy Efficiency (in all three sectors)	5%	21%	20%	26%
% of Electric Vehicles in the Transportation Sector	0%	36%	72%	72%
% of Electricity from Local Renewables	14%	63%	51%	71%
% of CO2e Reduction	33%	80%	80%	80%

Recommendations

(To be determined after public input process.)

References

[1] http://www.eia.gov/forecasts/AEO/MT_electric.cfm

[2] Census data 200-2010
[3] Census data 200-2010

[4] Tompkins County Transportation Council. Greenhouse Gas Summary 6_17_15

[5] http://nepis.epa.gov/Exe/ZyPDF.cgi/P100MKYR.PDF?Dockey=P100MKYR.PDF

[6] http://www.eia.gov/electricity/annual/html/epa_08_02.html

[7] http://www.eia.gov/environment/emissions/co2_vol_mass.cfm

[8] Cornell University Energy & Sustainability. Cornell Energy Resources. The Central Energy Plant.

[9] Tompkins County Transportation Council MOVES simulation results. The simulation started from 2015, and it was assumed that the growth rate holds true for a simulation starting from 2008

[10] https://www.energystar.gov/products/certified-products/detail/heat-pumps-air-source

[11] http://energy.gov/articles/history-electric-car

[12] http://www.teslamotors.com/models

[13] http://www.dos.ny.gov/dcea/energycode_code.html

[14] http://codes.iccsafe.org/app/book/toc/2015/I-Codes/2015%20IECC%20HTML/index.html

[15] https://www.energystar.gov/products/certified-products

[16] http://www3.epa.gov/otaq/climate/regulations.htm