Demand-Side Management

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Executive Summary

Demand-side management (DSM) encourages end users to modify their level and pattern of energy use. The objective of DSM is to provide cost-effective energy and capacity resources to help defer or avoid altogether the need for new sources of power, including generating facilities, power purchases, and transmission and distribution capacity additions [1]. In this section, we define DSM broadly to include energy efficiency, demand response, and distributed energy storage. Within energy efficiency, we study the potential for retrofitting existing buildings, constructing new energy efficient buildings, and utilizing heat pumps and solar thermal as energy efficient appliances. The main findings are summarized as follows.

Retrofitting existing buildings We first estimated the County-wide average site Energy Use Intensity (EUI) for residential and commercial buildings, respectively, based on utility and square footage data. Then we compared the County-wide site EUIs against benchmark values to quantify the potential for energy savings.

For commercial buildings, we adopted as the benchmark value the median site EUI for all LEED certified commercial buildings in the U.S. LEED stands for Leadership in Energy and Environmental Design. It is a set of rating systems for the design, construction, operation, and maintenance of buildings, homes, and neighborhoods. The potential was estimated to be 2,319,177 MMBtu in energy saving, or 68.7% reduction over the current level.

For residential buildings, we adopted as the benchmark value the site EUI of a local office retrofitted from an old house in Downtown Ithaca. The potential was estimated to be 2,286,693 MMBtu in energy saving, or 67.3% reduction over the current level. The total potential for retrofitting existing buildings is therefore 4,605,870 MMBtu, which is about 34.4% of the total energy consumption (including transportation) in the County. Retrofitting existing buildings has the largest potential among all energy efficiency measures, but is also the most challenging due to factors such as the large proportion of older housing stock in the County, lack of financial incentives for building insulation or home energy performance in general, and split incentives between tenants and landlords for energy efficiency in rental properties. On the other hand, there are a number of local initiatives being developed to help address those challenges such as the Residential Energy Score Project, Ithaca 2030 District, and South Hill Outreach for Rental Experience project.

Constructing new buildings

Heat pumps Scenarios were evaluated in which the entire heating and cooling demand in the County is served by Air-Source Heat Pumps (ASHP) or Ground-Source Heat Pumps (GSHP). The ASHP and GSHP scenarios would lead to significant increases in electricity consumption of ~523 GWh and ~262 GWh, respectively. At the same time, both scenarios would eliminate most of the natural gas and fuel oil consumptions in the County. In perspective, the total electricity consumption in the County at the 2008 level is ~779 GWh. One major technical challenge for

AHSP is the operation at extremely low ambient temperature, as the most efficient AHSP models do not operate below -13 °F. Supplemental heating sources are often needed for ASHP. In comparison, GSHP has no major technical challenges in operating at low temperature, but the installation costs for GSHP are high compared to AHSP.

Solar thermal We analyzed the roles of solar water heating in the future energy system in Tompkins County. Even though solar thermal is an efficient way to create hot water, lack of effective energy storage and siting flexibility makes solar thermal less appealing to residential and commercial customers. For buildings with substantial hot water usage, solar hot water heating systems remain a viable option to reduce the reliance of fossil fuels. For high renewable penetration scenarios where net metering is no longer feasible or for off-grid applications such as a microgrid, solar hot water heating systems serve as an efficient way to generate domestic hot water.

Demand response Demand response has played an important role in peak load reduction, and can potentially play a critical role in integrating intermittent renewable energy. We estimated the potential for demand response in the County based on a recent study on the effects of dynamic pricing on demand profiles in New York State. The results for NYISO Zone C (where the County is located), adjusted by the fraction of Zone C population in Tompkins County were applied to the County. The potential for peak load reduction is ~22 MW. The major challenge for expanding demand response is lack of dynamic pricing options for the customers. On the other hand, the development of automated demand response for commercial customers, home automation technologies and the Reforming Energy Vision (REV) initiative proposed by New York State will make demand response and dynamic pricing more accessible to the community in the near future.

Distributed energy storage The roles of energy storage are critical to improving system resilience and integrating renewable generation. We examined the feasibility of various types of energy storage, including thermal, mechanical, chemical, electrochemical, and magnetic, in Tompkins County. At present, only thermal storage systems have been implemented and only in the non-residential sectors. With intensive research efforts on energy storage currently being undertaken by universities in the Southern Tier Region and elsewhere in the world, and the potential development of a number of microgrids in the region, the County may see more examples of distributed energy storage in the coming years.

1. Introduction

This chapter discusses the potential, as well as opportunities and challenges, for the following aspects of demand-side management (DSM) that are closely aligned with Tompkins County's sustainability goals:

- Building energy efficiency (including retrofitting existing buildings, constructing new energy efficient buildings, and utilizing heat pumps and solar thermal as energy efficient appliances);
- Demand response;
- Distributed energy storage

Building energy efficiency

Existing buildings. In 2013, buildings' share of U.S. primary energy consumption was about 40.7% [3] and this figure was 51% in Tompkins County in 2008 for just the residential and commercial sectors; hence increasing energy efficiency in existing buildings is a critical step to address energy consumption and greenhouse gas emissions.

Energy efficiency in rental properties is a particularly difficult problem due to split incentives, where investments in energy retrofits and benefits from ensuing energy saving are not properly aligned among landlords and tenants.

New construction. New buildings can incorporate energy efficiency directly in their design and construction. It is more technically feasible and economical to design and build an energy efficient building than to retrofit that building at a later point in time [14]. Buildings can also be designed to be more suitable for renewable energy integration. For example, siting a building to have a south-facing roof that is wide, sturdy and gradually pitched, will allow for easier solar PV installation. A house that meets rigorous "passive house" standards for insulation and air sealing will reduce heat losses to an absolute minimum [54].

Heat pumps. Heat pump systems, including air-source heat pumps (ASHP) and ground-source heat pumps (GSHP), are considered energy-efficient alternatives to furnaces and electric heaters. Heat pumps keep houses warm in winter and cool in summer by transferring heat between indoor and outdoor environments.

Solar thermal. Solar water heating systems are mounted on rooftops, and provide an efficient way to generate domestic hot water.

Demand response

Demand response (DR) usually refers to reducing or shifting electricity usage by consumers during peak periods in response to time-based rates or other forms of financial incentives. DR programs are being used by electric system planners and operators as resource options for balancing supply and demand. Such programs can lower the cost of electricity in wholesale electricity markets, and in turn lead to lower retail rates. In the future, dynamic rate structures based on supply of intermittent renewable energy may incentivize flexible demand as forms of DR.

Distributed energy storage

Energy storage is crucial for DSM. Energy storage systems are designed to accumulate energy when production exceeds demand and to make that energy available at the user's request. Energy storage can help match energy supply and demand, exploit the variable production of renewable energy sources (e.g. solar and wind), and reduce greenhouse gas emissions [8].

2. Building Energy Efficiency

In this section, we describe the potential for improving energy efficiency for both existing buildings and new construction. In addition, we discuss the potential of deploying heat pumps and solar thermal as energy efficient appliances to meet the heat demand in the County.

2.1 Retrofits of Existing Buildings

Our approach for estimating the potential for energy savings through retrofitting existing buildings is to compare the Energy Use Intensity (EUI) calculated for buildings in the County with some relevant benchmark values. One of the key metrics to characterize the energy use of a building [55], EUI is calculated by dividing the total energy consumed by the building in one year (measured in kBtu) by the total gross floor area of the building. Generally, a lower EUI signifies better energy performance. Energy retrofits can reduce a building's EUI and save energy.

There is an important distinction that should be made between source EUI and site EUI. Source EUI is computed using source energy, which represents the total amount of raw fuel that is required to operate the building [55]. It incorporates all storage, transmission, delivery, and production energy losses. Site EUI, on the other hand, is computed using site energy, which is the amount of heat and electricity consumed by a building as reflected in the utility bills. Site EUI is always smaller than source EUI of the same building unit.

Building energy efficiency should be assessed by comparing equal performance metrics, i.e., comparing site EUI of buildings with site EUI of benchmarks, or comparing source EUI of buildings with source EUI of benchmarks. Unless otherwise noted, our analysis uses site EUI, since the energy consumption data at point of use (as quantified in utility bills) is readily available.

2.1.1 Potential for Existing Buildings

The County-wide average EUI can be estimated following its definition above. Table 1 summarizes annual energy consumption by buildings in the residential and commercial sectors and the corresponding EUIs.

Square footage data of each tax-reporting building and the corresponding property class in the County were extracted from Real Property Service data provided by the Tompkins County Assessment Department. It should be noted that the industrial sector is not included in our analysis, because energy consumption there is driven by types of industrial process rather than building energy efficiency [10][56]. Total energy consumption is the sum of electricity consumption and primary energy (i.e., natural gas, fuel oil, etc.) consumption in MMBtu/year.

Table 1. Site EUIs in the residential and commercial sectors in Tompkins County in 2008 [9]

	Residential	Commercial
Electricity Consumption (kWh/year)	293,371,081	347,749,634
Electricity Consumption (MMBtu/year)	1,001,266[a]	1,186,859[a]
Primary Energy Consumption (MMBtu/year)	2,394,857	2,191,074
Total Energy Consumption (MMBtu/year)	3,396,123	3,377,933
Total Floor Area (sq. ft.)	39,062,064	15,344,563
EUI (kBtu/sq. ft. · year)	86.94	220.14

[a]: Converted from kWh of electricity consumption

In perspective, the median value EUI for office buildings in the Northeast Region is 210 kBtu/sq. ft., according to the 2003 Commercial Building Energy Consumption Survey [76].

Another benchmark EUI is for a LEED building. LEED stands for Leadership in Energy and Environmental Design. It is a set of rating systems for the design, construction, operation, and maintenance of buildings, homes, and neighborhoods [57]. Buildings that obtain LEED certification are required to include building-level energy metering that represents total building energy consumption. Points are given for various energy performance improvements and the overall building is compared with a baseline building performance rating. Points are also awarded for renewable energy systems and improvements made for energy performance [82]. According to the report of Energy Performance of LEED for New Construction Buildings, the median EUI for all LEED buildings in the U.S. is 69 kBtu/sq., which is “24% below the national (commercial) building stock average from the 2003 Commercial Building Energy Consumption Survey for all commercial building types.” [11] Office buildings dominate the building categories in this study, and the remaining are mostly commercial buildings, including library, lab, and kindergartens. If all existing commercial buildings in the County were retrofitted to reach the national LEED building EUI median, potential energy savings are estimated to be 2,319,177 MMBtu, detailed in Table 2.

Table 2. Potential for energy saving in the commercial sector estimated using LEED median EUI as benchmark

	Commercial
Original EUI in 2008 (kBtu/sq. ft./year)	220.14
EUI Benchmark (kBtu/sq. ft./year)	69
Difference (kBtu/sq. ft./year)	151.14
Total Building sq.ft.	15,344,563
Potential for Energy Saving (Difference × Total Building sq. ft.) (MMBtu/yr)	2,319,177
Percentage Reduction	68.66%

Approximately 65% of the 2,319,177 MMBtu/yr potential for energy saving is estimated to come from heating energy upgrades. This proportion is obtained from table 1 by finding the percent of primary energy consumption accounts for in the total energy consumption for commercial buildings and assuming that building performance improvements apply equally to heating energy and electricity use of the building.

Another benchmark that can be referenced is the EUI of a local building after a “deep energy retrofit”. A deep energy retrofit is a whole-building analysis and construction process that uses "integrative design" to achieve much larger energy savings than conventional energy retrofits, typically resulting in savings of 30% or more [95]. Taitem Engineering’s small office building on 109 S Albany St. was selected as an example for this benchmark, due to the abundance of information

available and the fact that it is an example of what can be achieved when retrofitting older housing stock and small businesses, since the building is a re-purposed older house. The EUI of the building at 109 S. Albany Street was 115.9 kBtu/sq.ft. year in 2000, before any retrofit work was done. In 2013, after the deep energy retrofit work was completed, it was 28.4 kBtu/sq.ft. year [32].

If all existing residential buildings in the County were retrofitted to reach the EUI level of 109 S. Albany Str., the potential of energy saving is estimated in Table 3.

Table 3. Potential for energy saving in the residential sector estimated using 109 S. Albany St. EUI as benchmark

	Residential
Original EUI in 2008 (kBtu/sq. ft./year)	86.94
EUI Benchmark (kBtu/sq. ft./year)	28.4
Difference (kBtu/sq. ft./year)	58.54
Total Building sq.ft.	39,062,064
Energy Saving Potential (Difference × Total Building sq.ft.) (MMBtu/yr)	2,286,693
Percentage Reduction	67.33%

Approximately 71% of the 2,286,693 MMBtu/yr potential for energy saving is estimated to come from heating energy upgrades. This proportion is obtained from table 1 by finding the percent of primary energy consumption accounts for in the total energy consumption for residential buildings and assuming that building performance improvements apply equally to heating energy and electricity use of the building.

2.1.2 Challenges and Opportunities for Existing Buildings

a. Efficiency measures for energy retrofitting

Proven technologies to improve building energy efficiency have been practiced in the County for almost 25 years.

Electricity Measures for improving a building's efficient electricity use include, for instance, upgrading lighting systems. Both using the right amount of light and using efficient light bulbs are important [32]. The measures also include upgrading appliances, such as refrigerators, dryers, televisions, and computers, to more energy efficient models. Installing smart meters and other monitoring sensors to manage electricity use in a building is another measure that is effective in further reducing electricity consumption.

Heating/Cooling Measures for improving a building's heating/cooling energy use efficiency include weather-stripping, installing storm windows, ductwork and envelope air sealing and insulation, and replacement of HVAC equipment [32].

ENERGY STAR recommends levels of insulation that are cost-effective for different climates where a wood-framed building is located [83]. The County lies in Zone 5 by ENERGY STAR's classification.

Table 4. Recommended insulation levels for existing wood-framed buildings

Zone	Add Insulation to Attic		Floor
	Uninsulated Attic	Existing 3-4 Inches of Insulation in Attic	
5-8	R49 - R60	Add to R38 - R49	R25 - R30

Heat recovery ventilation (HRV), as opposed to regular mechanical ventilation, is an effective measure to reduce heat losses in air exchange between indoor and outdoor environments. This is especially important for well-insulated and airtight buildings in a heating climate like that found in the County. Cornell University has invested ~$45 million since 2001 to improve heat recovery capacities in campus buildings. Average savings per year from reduced fuel and electricity consumption on the Cornell campus is ~$5 million. According to Lanny Joyce, Director of Cornell Utilities and Energy Management, most residential and commercial buildings (including both residential and commercial ones) in the County do not have heat recovery features, likely because of the high capital expenses. It is common for the HRV system of a very air-tight building to have an installation cost of $4,000 to $7,000 or more [97].

Other measures that are suitable for existing buildings in the County include aerosol air sealing that reduces duct leakage to below 30 cfm, installing instantaneous gas water heaters, and replacing central ventilation with ductless air source heat pumps [32].

All of these improvements can be handled by an energy service company (ESCO). ESCOs develop, install, and fund projects designed to improve energy efficiency and reduce operation and maintenance costs in their customers' facilities [6].

b. Challenges and Opportunities in the Residential Sector

Capital and labor costs Capital and labor costs for building energy retrofits are high. Considering residential and small office buildings for instance, costs could vary from hundreds to tens of thousands of dollars to have the conventional weatherization done professionally [32]. The final price depends on multiple aspects of the building itself, including total square footage, degree of energy efficiency before the retrofits, and the desired performance afterwards. Residential buildings in the County tend to be relatively small and old, making for a poor economy of scale. Currently, low natural gas prices create projections for very long payback periods from building energy retrofit investments. Ian M. Shapiro, Chairman of Taitem Engineering, thinks that this probably is a major drawback hindering actions being taken by homeowners locally.

Federal tax credits. At the same time, federal residential energy efficiency tax credits were not extended for most home performance measures after they expired on Dec. 31, 2013 [33].

NYSERDA is gradually replacing tax credits and rebates with more market-driven solutions such as low-interest loans and green bank resources [89]. It remains to be seen whether this approach results in more or less adoption of energy efficiency measures [89].

Contractors Home Performance with ENERGY STAR (HPwES) offers a comprehensive, whole-house approach to improving energy efficiency and comfort of homes. Participating contractors are seen by consumers as more thorough than their competitors because the HPwES program includes third-party quality assurance checks on their work. The program, however, is also cumbersome and has high overhead costs associated with it, making it difficult for contractors to implement [84] [88]. Several participating contractors located in the County have withdrawn from the program over years, including ASI Renovations, Green Home Heros LLC, and Sunny Brook Builders [34]. Only a handful of HPwES participating contractors are still carrying out the program in the County, resulting in a deficit of supply in comparison with demand for retrofitting services.

Expected energy performance An additional challenge is that energy savings from building energy retrofits are not always predictable. Realization rate (i.e. delivered/predicted) of energy savings ranges widely from 0% to more than 100%. Multiple causes contribute to this uncertainty, including commonly overestimating runtime of lighting fixtures, difficulty estimating the energy saving from air sealing and insulation, behavior of building occupants and many others. Labor-intensive building energy retrofits, create jobs and economic benefits for the County. Switching the conversation from simple payback to benefit/cost ratio, or return on investment, when contractors discuss the results of energy audits with customers may allow building energy retrofits to be accepted by more homeowners. For example, simple payback on a new air source heat pump is ~3 years [98]. The same heat pump has a benefit/cost ratio over its lifespan (~15 years) of 5, and a ROI of 400%.

Multiple incentives from New York State are important in promoting home energy retrofits, including:

- Free or reduced cost energy audits
- 50% subsidy for mid-to-low income households (up to $5,000/household) for basic retrofitting works
- Free electric and home performance measures for low income households through EmPower New York (up to $8,000/household)
- and NYSEG rebates on high-efficiency equipment [88]

The Residential Energy Score Project (RESP) Representatives from Danby, Caroline, Ulysses and the City and Town of Ithaca, as well as Tompkins County and Cornell Cooperative Extension, successfully applied for a NYSERDA grant to develop either an ordinance or a voluntary program that would encourage all houses listed for sale to have an energy efficiency evaluation, which would then be made available to prospective buyers. RESP is currently being developed by a local consulting firm working with the consortium of partners.

Community marketing for energy efficiency The County can also take initiatives to incentivize home energy upgrades to supplement those available from the state. The Solar Tompkins Program could be a good model for a community-based approach. It combines community marketing with

NYSERDA quality control [36]. The program seeks to eliminate the few remaining barriers to solar adoptions by providing: 1) attractive lower-than-market pricing obtained through group buying, 2) a simple process with vetted technology and installation partners 3) educational outreach throughout the County on the practicality of solar PV and all-you-need-to-know-made-easy introductions to the technology, and 4) a community-wide program to build enthusiasm and generate the impetus for adoption now [61].

Trend in decreasing residential housing unit size It should be noted that the average size of residential housing units, including new and existing units, decreased between 2005 and 2009, though the causes behind this trend are unclear. The "great recession" may have influenced this trend, as well as increased interest in apartment living in urban areas. Data of average square footage for housing units within residential buildings in the northeast U.S. in years 2005 and 2009 are cited from Energy Information Agency Residential Energy Consumption Survey in Table 5.

Table 5. Average square footage for residential buildings in northeast U.S. over years [81]

Year	Housing Units	Average Square Footage Per Housing Unit			Average Square Footage Per Housing Member		
	Millions	Total	Heated	Cooled	Total	Heated	Cooled
2005	20.6	2,334	1,664	562	911	649	220
2009	20.8	2,121	1,663	921	836	656	363

c. Challenges and Opportunities in the Commercial Sector

Deep retrofits in small commercial buildings There are many opportunities to improve building energy efficiency in the commercial sector as well. A good example can be found in the retrofit work conducted by Taitem Engineering on its own office space in downtown Ithaca. Between 2002 and 2012, its engineering staff designed and implemented measures including weather-stripping, installation of storm windows, lighting improvements, ductwork and envelope air sealing and insulation, and HVAC plant replacement. After the energy retrofit work was completed, Taitem experienced electricity saving of 2,004 kWh/yr, gas saving of 1,033 therms/yr, and a 60% total reduction in energy use. The overall capital costs to do the work were about $40, 800 over the 10 years, and annual cost saving from the energy savings is about $1,764 [47]. Comfort inside the building was significantly improved as well after the renovation. Additionally, staff reports that it is much quieter working inside, and the indoor temperature is now well-controlled.

Ithaca 2030 District Across North America, 2030 Districts are forming, with support of Architecture 2030, to help the commercial sector use less energy and water in its buildings. 2030 Districts are unique private/ public partnerships that bring property owners and managers together with local governments, businesses, and community stakeholders to provide a business model for urban sustainability through collaboration, leveraged financing, and shared resources. Together they benchmark, develop and implement creative strategies, best practices and verification methods for measuring progress towards a common goal.

A group of people and organizations have been working for over a year to establish a 2030 District in Ithaca, aiming to reduce the energy usage of existing buildings in downtown Ithaca by 50% by 2030. So far the project has nine building owners committed to joining the District and is working

on officially launching the District in 2015 [93]. By joining the District business leaders in the Ithaca community will gain three primary benefits: 1) the ability to share data and best practices regarding their efforts to improve building energy efficiency; 2) the ability to use the 2030 District brand name in marketing materials and 3) access to financing opportunities and bulk purchasing initiatives [62]. The Ithaca 2030 District just received a one-year planning grant from NYSERDA to further explore and develop the District and its potential to reduce energy use in the commercial sector.

Energize NY Commercial Property Assessed Energy Both the City of Ithaca and Tompkins County have adopted legislation to enable property assessed clean energy (PACE) commercial financing locally. The PACE program would offer low-cost long-term financing for energy efficiency and renewable energy projects, supporting up to the entire project cost, for owners of existing non-residential properties, with repayments collected by the municipality through a charge on the tax bill. Having the costs and benefits of the energy improvements run with the land and repayment over many years may make it feasible for more building owners to make investments in energy retrofits.

Split incentives for energy efficiency in rental properties According to American Community Survey data, 42% of the housing units in Tompkins County are renter occupied. In rental properties there is a mismatch between who pays for the upgrade and who reaps the rewards of lower energy bills. Typically, renters pay utility bills and landlords pay for retrofits. With this system, landlords invest in their buildings, but see no payback through reduced utility bills since those are paid by renters. The only way for landlords to recoup the retrofit investment is for them to raise the rent, which can make it less attractive to new tenants. Conversely, if the landlord pays utility bills, there is little incentive for renters to save energy [37]. Such split incentives, also known as the landlord/tenant dilemma, is particularly striking in the City of Ithaca with its high proportion of housing units are student rentals [38]. Split incentives not only exist in residential buildings, but in commercial buildings especially rental office buildings as well.

One example of a successful pilot project that significantly increases energy efficiency in rental properties is the South Hill Outreach for Rental Experience (SHORE). This project runs an off-campus housing lottery system combined with workshops-quizzes and incentives such as cash rebates that can be applied to rent payments. The program educates Ithaca College students about energy efficiency in apartments/dormitories and encourages them to save energy. Energy savings are measured and cash prizes and rebates are awarded to students at the end of each academic year. Other aspects of the project focus on ways to motivate behavior change in both landlords and tenants. Actions, such as certifying tenants' energy use behaviors and creating an online platform that broadcasts each rental unit's energy use information, are being piloted to gage behavior change.

Green leasing may be a promising opportunity to solving the energy conservation and efficiency problem in rental properties. Green lease is an attachment to a regular lease, so both tenants and the landlord would have the same information about the premises, which include the investments required to improve the rental's energy efficiency, whichever party makes them, and what the calculated savings would be. The tenant accepts a higher rent for a period of time and gets the benefits of energy savings. Legislation is needed to clearly indicate how much the landlord can

increase the rent and protect tenants' rights when accepting or rejecting the proposed rise in rent. The lease should eventually lead to reduced costs for both parties and a better image for the landlord's company (and possibly the tenants) [39].

Other than the contractual solution, some regulatory changes may include disclosure of building energy performance information (i.e. energy labeling) for tenants' reference and regulators' supervision, and municipal ordinances that outline the minimum energy efficiency requirements for rentals (i.e. tightening the building codes) [38]. Integrated with local financing programs that target reducing initial energy upgrade costs, these approaches, tailored to rentals, may make positive contributions to overcoming the split incentives barrier. [41]. At present, they are not sufficient at the state level, which is partly because of property rights issues. [38]. In essence, finding the right motives for behavior changes in both landlords and tenants is key to addressing the problem[1].

NYSERDA's Multi-Family Home Performance Program (MPP) In May of 2007 NYSERDA launched the Multi-Family Home Performance Program (MPP), which challenged all participating projects to reduce their total source energy consumption by 20% and awarded a "New York Energy $mart Building" performance indicator (in the form of a plaque) to each successful existing building project [60]. In order to evidence achievement of the performance target, projects are required to enter twelve months of pre and post retrofit energy usage into a benchmarking tool developed by Oak Ridge National Laboratory. The benchmarking tool converts this consumption data to source energy values using different factors for all fuel types, and then applies a regression analysis to it. The result is a weather-normalized total source energy reduction value, which is expressed as a percentage of the baseline year's use. Projects that achieve or exceed 20% reductions receive additional incentives from NYSERDA.

The program has achieved relative success thus far. The 20% target appears to be a well placed goal for the program. The observed average energy savings per project was 19.7%. Rather than providing a one-size-fits-all solution to different building types, the MPP allows for flexibility to install cost effective measures dependent upon the unique circumstances faced by each building. A review by NYSERDA of the first 17 projects to complete the MPP revealed that 59% of the projects in the dataset achieved the 20% performance target, while those that missed the target goal did so by a considerable margin. Because the Multifamily Performance Program was conceived to be a market transformation initiative, accurate savings predictions on a project-by-project basis are crucial [60]. Moving forward NYSERDA must investigate the underlying causes behind deviations in modeled savings. Focusing in on these issues will allow for better protocols to meet energy savings in the future [60].

2.2 Energy Efficient New Constructions

Ideally, a new building can be constructed to be a very well-insulated, virtually air-tight building that is primarily heated by passive solar gain and by internal gains from occupants, lighting (compact fluorescent), appliances, cooking, and other heat sources [12]. Energy losses are minimized and extraordinary reductions in carbon emissions can be achieved.

[1] A more detailed description and analysis of project SHORE can be found at the Appendix.

NYSERDA gives a guidance for designing residential construction that is highly energy efficient. Low-cost efficiency measures include smaller building size, simplified building shape, orienting the long axis of the building to East and West to allow for passive solar gain and make it ready for solar PV installation, tuned glazing (higher Solar Heat Gain Coefficient on South wall, lower on West walls to reduce cooling loads), and distributed HVAC, in addition to the conventional measures introduced in the previous section on Retrofits of Existing Buildings. Incorporating these elements at the beginning of the design process impacts the home's comfort, durability, and resource consumption throughout the life of the building [85]. Of course, in addition to the actual design of the building, location of new homes and businesses in areas with available water and sewer infrastructure, robust transit service, and in close proximity to jobs and services will result in significant energy savings in the long run.

Passive House A house that is designed and built to a strict set of energy efficiency and construction guidelines can qualify to achieve Passive House Certification. These are very well-insulated, virtually air-tight buildings that are primarily heated by passive solar gain and by internal gains from occupants, lighting, appliances, cooking, and other heat sources [12]. Energy losses are minimized and extraordinary reductions in carbon emissions are made possible.

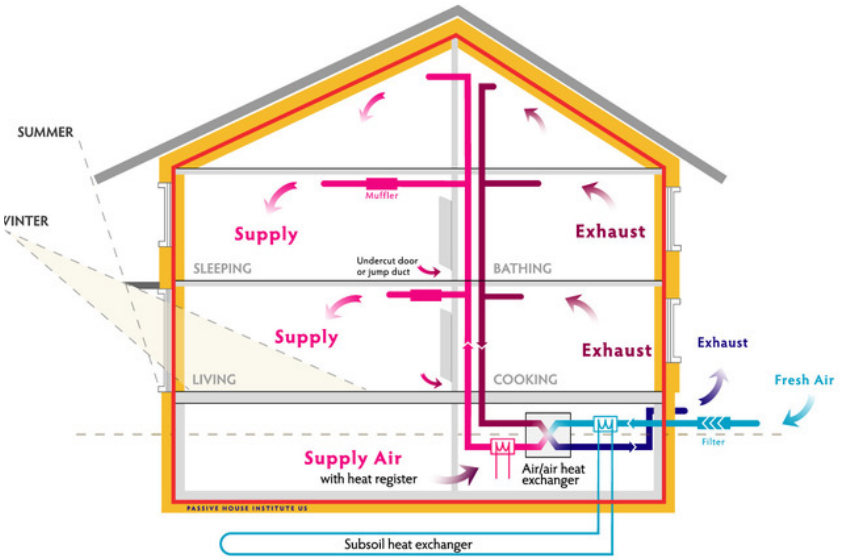

Figure 1. Passive House Basics [58]

At present the County boasts an award-winning sustainable community, EcoVillage at Ithaca (EVI), and several other pilot projects following its model, such as the Aurora Street Pocket Neighborhood (APN). The newest homes in EVI's Third Residential EcoVillage Experience (TREE) constitute the largest Passive House development in North America, with 7% of all Passive House units in the United States. The TREE homes showed an average savings of 78% over a typical Tompkins County household, and TREE homes that also opted to install solar PV achieved a 92% average savings, with several at or close to net-zero operation[49]. TREE and APN both received funding under the U.S. EPA's Climate Showcase Communities to document and publicize the performance of their buildings [13].

2.2.1 Potential for New Construction

Highly energy efficient houses, including Passive houses, focus on interdependent thermodynamic components, and appropriate building elements differ across climate zones. To learn about the energy systems of passive houses in the County, the Modisher/Frenay Residence on #12 200 Creamery Road, Brooktondale on was visited on Oct. 5, 2014.

The house provides a living area of ~2,000 sq.ft. and was expected to be completed by the end of 2014. Some of its energy features include:

- Super insulated (R-90 roof, R-49 walls, R-20 below slab) and air-tight
- Triple pane European windows (R-7.8, double gasketed, no low-e coating, for heat gain from sunlight is encouraged in this climate)
- Domestic solar water heating (two panels on the barn next-door)
- Air-source heat pumps for primary heating and cooling (12,000 Btus * 2 indoor units)
- RenewAire ERV ventilation system, 85% heat recovery of outgoing air (once every 3 hours) [15]
- All electric mechanicals, ready for PV system to create a net zero house (attached to the power grid for now)
- Heating EUI: 4.68 kBtu/sq.ft. year (reduced by 80%-90% compared to regular homes)
- Overall EUI: 15.2-26.7 kBtu/sq.ft. year

Apart from the Modisher/Frenay Residence, there are ~25 houses in the County that meet passive house standards. Most of them are in EcoVillage. These homes have similar energy features. For instance, their insulation R-values are in the consistent ranges: R-50 - 60 for walls, R-20 - 40 for floors, R-70 - 120 for ceilings, and around R-7 for windows. Most of them have an overall EUI around 26 kBtu/sq.ft. year as well.

Recently one year of energy consumption data was compared between one home in EVI, a 2013-generation Passive House, and another home there, a 2002-generation ENERGY STAR certified house. The Passive House used slightly more electricity, but consumed no natural gas at all. Overall the EUI of the Passive House is much smaller than that of the ENERGY STAR certified house.

Table 6. A comparison between a Passive House (336 Rachael Carson Rd., Ithaca, referred in chart as “336”) and an Energy Star-certified house (223 Rachael Carson Rd., Ithaca, referred in chart as “223”) based on one year worth of utilities data.

Address	Passive House Certified	ENERGY STAR Certified
Building Energy Feature	2013-generation Passive House	2002-generation ENERGY STAR certified
Interior Conditioned Living Area	1,450 sq. ft.	1,800 sq. ft.
Electricity Consumption (Nov. 2013 – Oct. 2014)	3,032 kWh	2,596 kWh

Natural Gas Consumption (Nov. 2013 – Oct. 2014)	0	812 therms
Overall Site EUI	7.13 kBtu/sq. ft. year	50.02 kBtu/sq. ft. year

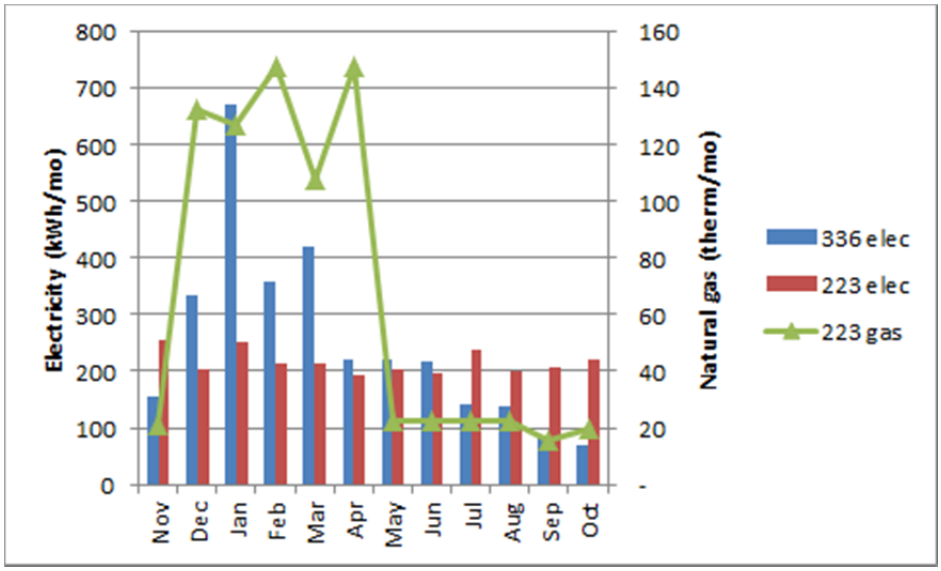

Figure 2. Energy consumption of a Passive House and an ENERGY STAR certified house [92]

The potential growth of Passive House construction in the County, however, is hard to determine, as Passive House building methods are new to this area but the ability to build extremely efficient homes in this area has been clearly documented.

2.2.2 Challenges and Opportunities for New Construction

a. Economic

As stated earlier in this chapter, it is often costly to retrofit an existing building to become very energy efficient. This is not necessarily the case when constructing new buildings, where it can be a relatively minor capital investment to achieve significant energy efficiency levels. This sentiment was confirmed by Benj Sterrett, a technical consultant on the Modisher/Frenay Passive House residence from Ironwood Builders. He gave the example of when a conventional central heating system (~$6,000 avg.) is replaced, under Passive House standards, with insulation and distributed heating units. The costs of installment are close to the same; however the latter system saves more on heating energy costs over its life cycle. Building the Modisher/Frenay residence costs only ~5% more per sq. than building a regular house in the County and homeowners will see significant energy savings for the life of the home.

Another example is the Hickory Hall dormitory at Emory and Henry College, located in Emory, VA. Hickory Hall was designed by Adam J. Cohen, founder of Passive Structures, LLC [18], and was completed in 2012. Hickory Hall meets the Passive House standards and has energy features similar to the ones listed for the Modisher/Frenay residence. Yet Hickory Hall has two unique characteristics. One is capital cost. The cost of building Hickory Hall was $118.25/sq.ft., which is about $6.75/sq.ft. lower than that of Elm Hall, a LEED certified dormitory located in the same

residential quad. Hickory Hall has much higher insulation values, energy recovery ventilation instead of raw outside air for ventilation, and geo- and solar-thermal heating. Passive House design allows Hickory Hall to minimize heat losses and maximize useful internal heat gain. Overall, Hickory Hall has a heating EUI of 1.62 kBtu/sq.ft. year and an energy performance ~62% below Elm Hall. Hickory Hall is also remarkable for its size as a passive house. Passive house design typically is more suitable for smaller houses, for which it is easier to guarantee air-tightness. Hickory Hall occupies ~40,000 sq.ft. and has a three-floor modular wooden construction. It proves the technical feasibility and opens up opportunities of passive house design for large buildings.

On November 18, 2014 the New York State Fire Prevention and Building Code Council voted to adopt an update to commercial provisions of the Energy Conservation Construction Code of New York State (ECCCNYS) [108]. The ECCCNYS establishes minimum requirements for energy-efficient buildings using prescriptive and performance-related provisions, and makes possible the use of new materials and innovative techniques that conserve energy. The ECCCNYS 2014, which will primarily effect Commercial building construction and renovation, has an effective date of January 1, 2015. However, the ECCCNYS does not directly translate into corresponding EUI and has a number of drawbacks. For example, the ECCCNYS only applies when at least 50 percent of an existing building's system is replaced, which meant most renovations in the County will not be covered. Several local governments have adopted more stringent energy codes [109]. A notable example is the New York City Energy Conservation Code (NYCECC), which has undergone several changes since its adoption in 2009.

b. Technical

Similar to the situation for existing buildings, there is a need for more designers, contractors, and builders in the County to meet the growing demand for more energy efficient buildings, as well as Passive House buildings. Obstacles for Passive House, in particular, include very high, prescriptive standards that make certification difficult to obtain.

Another misconception about very air-tight building is ventilation. Mechanical ventilation, for example, is preferred in passive houses. Opening windows for raw air ventilation actually causes more energy consumption. Not being able to open windows may make occupants feel uncomfortable, though the operation is completely healthy objectively.

The high-tech design also requires careful maintenance, which may not be convenient or desirable. One typical concern is moisture control. Daily water uses contribute to indoor humidity. In a highly energy efficient and air-tight house, the moisture level is balanced mechanically by a dehumidifier or an energy recovery ventilation system, otherwise excess moisture can cause mold growth and air quality deterioration. Not being able to maintain a healthy and comfortable living environment in an easier way, such as opening windows, may hinder the growth of air-tight buildings.

Last but definitely not the least, homes that rely solely on one source of energy, such as electricity, face certain risks [94]. In a very tight building envelope, the indoor air quality can decline very quickly if the ventilator fails. And if the heat pumps fail in the middle of a cold winter, no external energy sources would be available to aid heating [108].

2.3 Heat Pumps: Electricity-Powered Heating/Cooling Devices

2.3.1. Introduction

Heat pumps are essentially electricity-powered heating/cooling devices, extracting heat from outside to use inside a building for heating or in reverse for cooling purposes. Most heat pumps require indoor and outdoor components. For an Air-Source Heat Pump (ASHP), the outdoor component is usually a coil that transfers heat with outside air (Figure 3). For a Ground- Source Heat Pump (GSHP), the outdoor component is typically pipes buried in the ground that transfers heat with the earth (Figure 4).

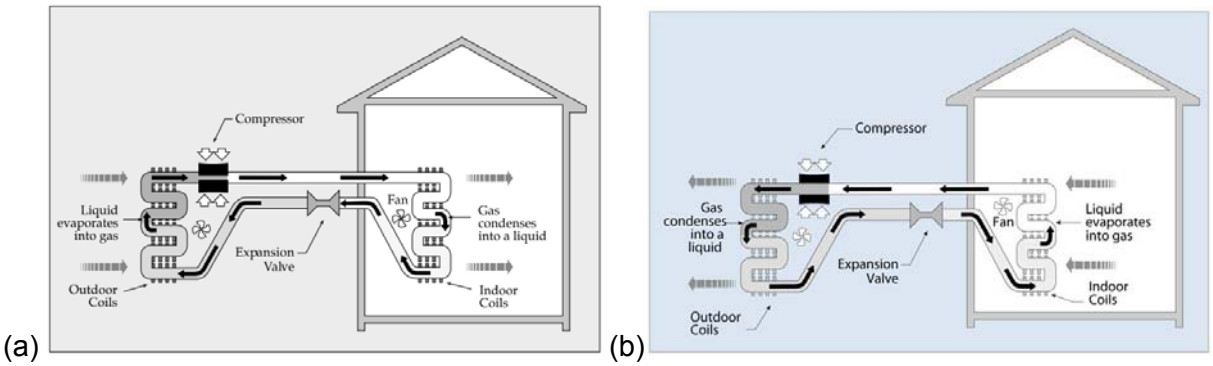

Figure 3. (a) A split-system air-source heat pump cooling cycle; (b) A split-system air-source heat pump heating cycle [64]

Compressors and expansion valves are often used to help circulate refrigerants between the outdoor and indoor parts. In a cooling cycle of an ASHP, as is depicted in Figure 3(a), the refrigerant is compressed before it enters the outdoor loop, so that it can release heat into outside air during the condensing process. The condensed refrigerant then goes through the expansion valve to enter the indoor loop, and evaporate to absorb heat. The cycle is reversed in winter by switching the refrigerant flow direction, as is depicted in Figure 3(b), so that it can bring heat from the outside to the indoor environment.

Most GSHP systems are closed-loop, circulating refrigerant through plastic (typically polyethylene) tubing buried in the ground or submerged in water. A heat exchanger transfers heat between the refrigerant in the heat pump and the refrigerant in the closed loop. The loop can be in a horizontal, vertical, or pond/lake configuration (Figure 4). A horizontal loop field installation usually occurs in more rural areas or yards with lots of space, and typically requires no drilling (and therefore has lower cost) is needed. The horizontal trenches are only a few feet deep (but below the frost line) in order to lay the piping. A vertical loop field is the most common installation for a GSHP that is installed on smaller properties. A series of holes are drilled, each between 50-400 feet deep.

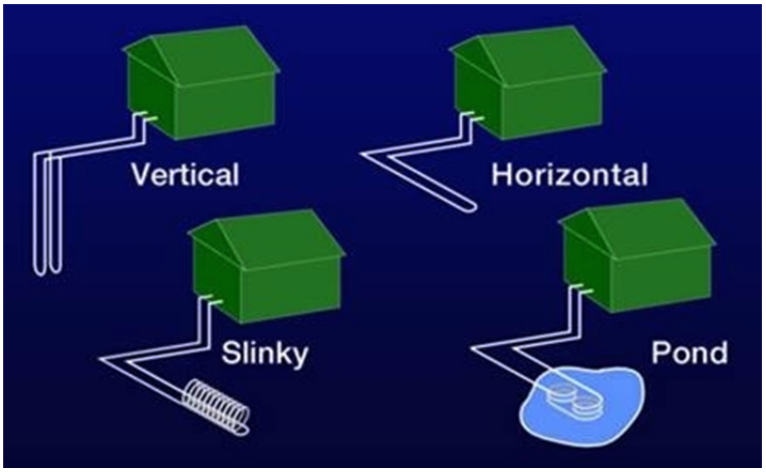

Figure 4. Types of heat exchangers for closed-loop geothermal heat pumps [99]

The ratio of useful heat movement per work input, i.e. heat gained versus electricity used, describes the performance of heating systems. It is also known as the coefficient of performance (COP). When properly installed, the COP of an ASHP can reach 2.2-3.8, the COP of a GSHP can reach 5.0-7.2, while the COP of an electric heater is only 1 [63]. This is due to the fact that instead of converting heat from electricity or fuel, heat pump systems move heat between different environments, which allows for higher efficiency.

Table 7. Comparison between GSHP and ASHP

Space Heating/Cooling Systems	GSHP	ASHP
COP	5.0-7.2 (low temperature output) [70]	2.2-3.8 [70]
Installation Cost	High	Low
Limitation	Local geology	Local climate
Operation	Simple	Simple
Expected Life Time	+20 [72]	10-15 [73]

The installation of GSHPs is currently expensive; a closed-loop GSHP might cost up to $20,000 [66]. Despite of the high installation cost, a GSHP has a higher COP than an ASHP and makes less noise. According to the U.S. Environmental Protection Agency (EPA), GSHPs can save up to 44% of energy compared with ASHPs [66]. This is because, compared with the air, the earth has more constant temperatures, which supports better system performance. Also, the temperature differences between heat sinks are usually smaller in a GSHP system [65]. It needs to be noted, however, that the installation of GSHPs always need more space.

ASHPs, on the other hand, have lower installation costs. Yet because heat pump efficiencies vary with the temperature differences between heat sinks, the cold climate in the Northern U.S. has

been a barrier for ASHPs - in winter, the COP of an ASHP drops along with the outside air temperature and an ASHP system sometimes needs to be combined with extra space heating . However, newer ASHP models are addressing these concerns.

2.3.2 Potential for heat pumps

According to the 2008 Tompkins County Community Greenhouse Gas Emissions Report [74], the total energy demand for heating and cooling in 2008 was 5,208,990 MMBtu, which is about 39% of the County's total energy consumption. Assuming that heat pump systems could be used to meet all the space cooling, water heating, and space heating energy demand (again, assumed to be 10% of total electricity use), and adopting a conservative average COP of 2.5 for ASHP and 3.5 for GSHP [78], around 23% - 28% of the County's total energy consumption could be saved relative to the 2008 level.

Table 8. Electricity consumption for heating and cooling by using heat pumps

Sectors	Heating and Cooling Total [MMBtu]	ASHP Electricity Consumption for Heating and Cooling (GWh)	GSHP Electricity Consumption for Heating and Cooling (GWh)
Residential	2,407,348	441	274
Commercial	2,251,815	413	257
Industrial	549,827	101	63
Total	5,208,990	955	594

The analysis suggests that if the County met the total heating and cooling demand by either ASHP or GSHP, the amount of electricity consumed by heat pumps would be ~955 GWh or ~594 GWh annually, on the same order of magnitude of total electricity consumption at the 2008 level, which is ~779.3 GWh. Furthermore, extensive use of heat pumps will likely create high peak demand which the current power system may not be equipped to handle based on existing infrastructure.

81.7% of thermal energy use in the County in 2008 comes from natural gas, 10.4% from propane, and 6.0% from heating oil. Switching to GSHP, for instance, to meet the total heating and cooling demand would offset the use of ~30,398,180 therms of natural gas, 4,250,475 US gallons of propane, and 1,609,813US gallons of heating oil consumed on site.

2.3.3 Challenges and opportunities for heat pumps

Integration with Renewable Electricity Heat pump systems are known for their high energy efficiency. The only energy a heat pump consumes is electricity, which means when combined with renewable electricity, e.g. electricity generated from PV Farms, a heat pump system will be able to provide high efficiency heating with zero greenhouse gas emissions.

Peak Demand Management It is well known that temperature-sensitive air conditioning (cooling) load drives summer peak electricity demand. Similarly, high penetration of heat pumps will create temperature-sensitive load in winter and consequently increase winter peak electricity demand. In addition, heat pumps-driven winter peak demand will likely occur in neighborhoods that never experienced peak demand before since the use of air conditioning is not substantial in the County. Managing the peak demand will require sufficient supply during peak time, adequate infrastructure (e.g., transformers in distribution systems) and peak-load reduction strategies. For example, integrating heat pumps with thermal storage turns heating demand to flexible demand, which allows end users and/or energy services providers to apply optimal control in order to reduce the impacts on power systems.

Operations at Low Ambient Temperature ASHPs equipped with variable speed compressors have greatly improved the efficiency at low ambient temperature. The most efficient ASHP models that are commercially available only begin to lose significant heating efficiency at 5°F, and continue to provide sufficient heat for typical homes down to -13 °F. In 2013, the National Renewable Energy Laboratory performed a study on the low temperature performance of air source heat pumps. In this study, they tested a specifically designed low temperature heat pump for two consecutive winters and evaluated its COP for each winter. The pump was found to operate with a COP of between 2.68 and 3.29 for this time period, depending on season and calculation method, and economically preferable to a comparable oil heating method. This study indicates that air source heat pumps may be viable in low temperatures previously discounted.[2] GSHP's, on the other hand, have never had a major issue with low temperature performance. This is because they draw their heat from underground where temperatures are barely affected by changes in surface temperature.[3]

Safety Another advantage of using heat pump systems instead of furnaces is safety. There is no need to worry about carbon monoxide or fire accidents. A heat pump system, especially an ASHP, is also very quiet and does not require much maintenance.

Versatility Heat pumps can provide not only space heating/cooling, but also domestic hot water. Air source heat pump water heaters are typically equipped with electric resistance elements that kick in whenever the heat pump cannot keep up with the demand for hot water [100]. According to a recent test of 15 heat pump water heaters in New England, the monitored COP was 1.9 [106], compared operating COP of 0.9 for an electric-resistance water heater. While efficiency is excellent, heat pump water heaters require installation in an indoor space with temperatures in the 40º–90ºF (4.4º–32.2ºC) range year-round and at least 1,000 cubic feet (28.3 cubic meters) of air space around the water heater [1] [105].

Installation and maintenance ASHPs are mostly ductless, and installations are relatively straightforward. The outdoor portion of the ASHP is visible (and occupies space) and requires some maintenance. Because drilling and digging are required, installations of GSHPs are much more invasive. After installation, there are not visible outdoor structures. Some components of the GSHP systems such as water pumps and electronics need regular maintenance.

[2] http://www.nrel.gov/docs/fy13osti/56393.pdf
[3] http://energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf

Aesthetics ASHPs are often installed in each room in a house and resemble air conditioner units located in the mid-to-upper area of the wall. This aesthetic is unattractive to some homeowners.

2.4 Solar Thermal Systems

Solar energy can be harnessed by different types of solar thermal collectors to meet heating/cooling demand or to generate electricity. There are a broad spectrum of applications, such as solar water heating, solar space heating, solar cooling, and concentrated solar power. In this report, we focus on the most promising application in Tompkins County, which is solar water heating.

There are various kinds of solar water heating systems.

- **Controls**: Active solar water heating systems have circulating pumps and controls, and passive systems do not. Figure 5 illustrates an active residential solar water heating system. Passive systems are typically less efficient, but also less expensive and more reliable.
- **Collectors**: Flat-plate collectors are glazed, insulated boxes containing copper tubing mounted on black-painted copper absorber plates. Evacuated-tube collectors consist of an assembly of glass cylinders, each enclosing a partial vacuum. Flat-plate collectors typically cost less, and perform better than evacuated-tube collectors. Evacuated-tube collectors, however, perform better during cloudy weather.
- **Freeze-Resistant**: Solar water heating systems need to be protected against freeze damage. There are two general approaches to do this. A drainback system removes all the fluid from the collector when the ambient temperature is low. An antifreeze system circulates an antifreeze solution through the collectors.

It should be noted that solar water heating systems almost always require a backup system for cloudy days and times of increased demand. The backup system can be an electric water heater or natural gas water heater.

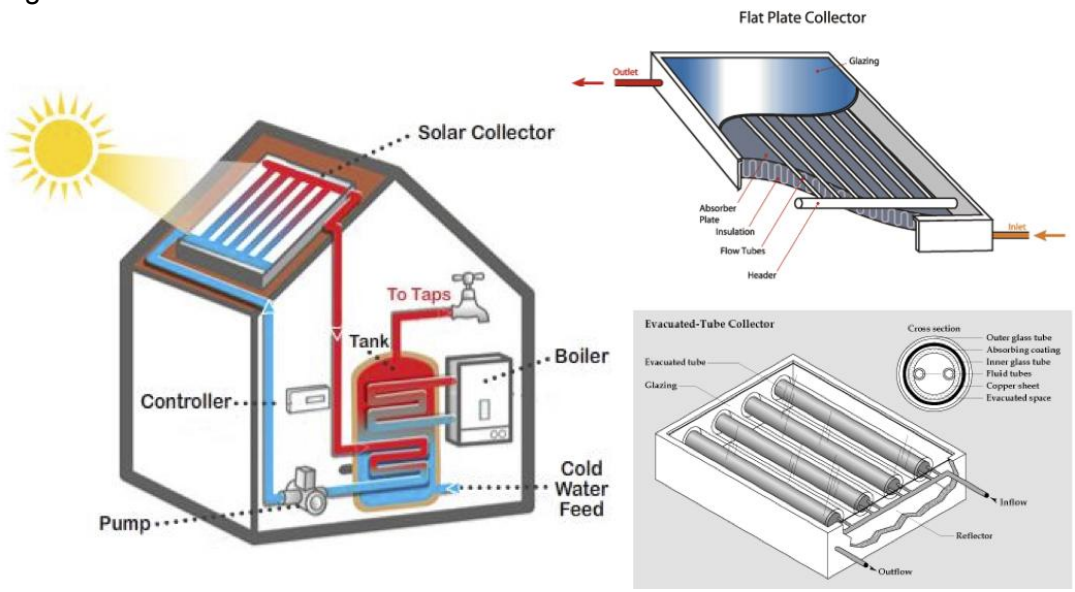

Figure 5. An illustration of a solar water heating system and two types of solar collectors

2.4.1. Potential for solar thermal

Given the constraints identified below, it was considered that the potential for deployment of solar thermal in Tompkins County was included in the analysis of solar PV.

2.4.2. Challenges and Opportunities for solar thermal

Lack of Energy Storage At present, most of the photovoltaic (PV) systems in Tompkins County are grid-tied, and net metering essentially allows PVs to use the grid as free, all-year-round energy storage, which is a big part of the incentive for installing PVs. In contrast, there is no effective energy storage for solar water heating systems, which typically produce more hot water than demanded in the summer, and less than needed in winter. Lack of effective energy storage makes solar water heating systems economically less attractive than PVs for residential customers, who usually cannot afford, or do not have enough roof area available, to install both PV and solar water heaters.

Viable applications For buildings with substantial hot water usage, or demand that coincides with times of high solar availability, solar hot water heating systems remain a viable option to reduce the reliance on fossil fuels. For high renewable penetration scenarios where net metering is no longer feasible or for off-grid applications such as a microgrid, solar hot water heating systems serve as an efficient way to generate domestic hot water.

3. Demand Response

According to the Federal Energy Regulatory Commission, demand response (DR) is defined as "Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized." [104] Methods of engaging customers in demand response efforts include offering time-varying rates such as time-of-use pricing, critical peak pricing (CPP), variable peak pricing (VPP), real time pricing (RTP), and critical peak rebates [101]. CPP, VPP and RTP also belong to a category called dynamic pricing because the prices depend on utilities and market conditions. Demand response also includes direct load control programs which provide the ability for power companies to cycle air conditioners and water heaters on and off during periods of peak demand in exchange for a financial incentive and lower electric bills. At present, both Independent System Operators/Regional Transmission Organizations, who oversee the wholesale electricity markets, and utility companies, who manage the retail electricity markets, offer demand response programs.

The New York Independent System Operator (NYISO) has four DR programs available to large institutional users or energy aggregators, namely the Emergency Demand Response Program, the ICAP Special Case Resources program, the Day Ahead Demand Response Program, and the Demand Side Ancillary Services Program. Commercial, industrial and institutional customers in Tompkins County who can reduce their electricity load by at least 100 kilowatts can participate in the Emergency Demand Response Program through New York State Electric and Gas Corporation (NYSEG)'s CA$HBACK (voluntary response) and CA$HBACK plus (obligated response) programs.

Several institutions such as Cornell University and the Ithaca Area Wastewater Treatment Facility are currently participating in the Emergency Demand Response Program.

While most residential customers are paying flat electricity prices, NYSEG offers two time-varying rates to residential customers in the County, i.e., Day-Night Service Rate and Time-of-Use Rate. Residential customers have to sign up for those rates. Both of these are considered “dynamic pricing” because they vary with peak electricity demand. With the Day-Night Service Rate, the nighttime service rate per kwh is about two-thirds the cost of the daytime service rate. However, there is a higher monthly meter charge, and the cost per kwh for electricity used during the daytime service hours is higher than the regular residential service rate. The Time-of-Use Rate varies the service rate based on on-peak, mid-peak and off-peak usage. This approach incentivizes using electricity during mid-peak and off-peak periods. A local example that is using the Time-of-User Rate is Gun Hill Residences, an apartment complex near Cornell campus. All residents pay Time-of-Use Rate by default. All habitable rooms in the Gun Hill Residences are equipped with electric heaters with highly insulated storage cores of dense ceramic material, which can store heat during off-peak hours and release heat when needed.

Energy storage is crucial for demand response. It is discussed separately in Section 4.

3.2 Potential for Demand Response

Dr. Zhang’s research group at Cornell University conducted a study on the effects of dynamic pricing (specifically critical peak pricing, or CPP) on demand profiles for each NYISO zone based on the 2008 data. Tompkins County is in NYISO Zone C. Two cases were compared: flat price and dynamic price. The methodology used in the study is briefly described as follows.

First, electricity prices were calculated for each of 12 NYISO zones based on three components: energy charge, capacity charge and other non-generation charges. Energy and capacity charges were calculated separately for the flat price and dynamic price cases, while other charges were assumed to be the same for both cases. Then the charges were combined to determine flat and dynamic electricity prices.

Next, demand elasticity was applied to the ratio of dynamic to flat charges to evaluate the effects of dynamic pricing on the demand. Demand elasticity was derived based on the results from several pilot experiments on rate designs and price elasticity evaluation [110][111][112]. The relationship between dynamic/flat price ratio and the amount of peak reduction was quantified as a logarithmic model. The logarithmic model of elasticity curve was extrapolated to capture the load shifting in off-peak times, shown in Figure 6. The experiments with enabling technology, such as in-home displays and programmable thermostats, produced larger demand reduction, thus it was described in a different curve. The logarithmic model showed that the amount of demand reduction rose at a decreasing rate with the increasing of dynamic/flat price ratio. During peak time, the dynamic/flat price ratio was larger than 1, while during off-peak time, the ratio was smaller than 1. In our base case, the load reduction during peak time was up to 16% with the price ratio around 8, and the load increase during off-peak time was up to 7% with the price ratio around 0.36. In the base case with enabling technology, the maximum load drop is 23.7%.

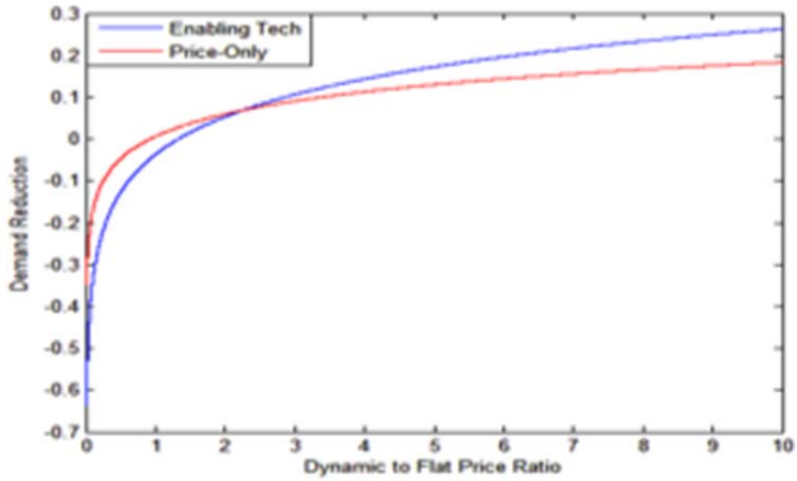

Figure 6. Demand curves derived from dynamic pricing pilot experiments [102]

Figure 7 illustrates the comparison of the load duration curves (LDV) for Tompkins County with and without dynamic pricing. We only show hours from June 1 to September 30, 2008, referred to as "summer hour". The baseline LDV was constructed by downscaling the 2008 load data for Zone C by the population fraction in Tompkins County over the total population in Zone C, which is ~6.3%. The results suggest that the peak demand (i.e., the y-intercept on a LDV) can be reduced as much as 21.8 MW.

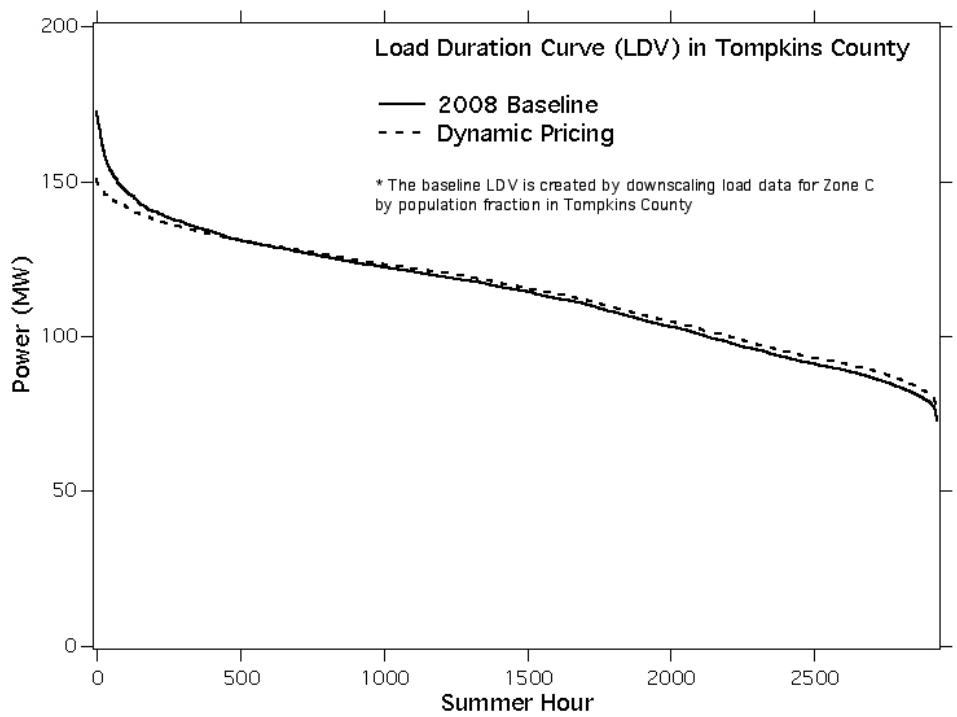

Figure 7. Tompkins County Load Duration Curve with and without demand response resulting from dynamic pricing [80] [81]

3.2 Challenges and Opportunities for Demand Response

Dynamic pricing The key driver for demand response is pricing signals. Because a majority of the retail customers pay flat (or static) rates, the demand side of the electricity market has historically

been unresponsive to the cost of supplying electricity, which varies significantly throughout the day and over the course of the year. In the near term, dynamic pricing gives customers greater control over their electricity bills by allowing them to modify their energy use patterns based on prices. In the intermediate term, dynamic pricing can help reduce greenhouse gas emissions by incentivizing shifting demand toward times when the electricity is generated by renewable resources. A major regulatory reform in Reforming the Energy Vision (REV), as proposed by New York State Department of Public Service, is rate design changes, providing "dynamic price signals that reflect system needs and costs over short and long term horizons". We expect to see more dynamic pricing options to retail customers in Tompkins County.

Technology development Utilities companies in California use a platform called Automated Demand Response (ADR) [103] to automate this energy curtailment process at commercial and industrial facilities. ADR makes it easier to participate in demand response programs and makes the response more reliable. Using modern control equipment such as building management systems and lighting control systems, utility companies can send a remote signal to demand response facilities to initiate an automatic, pre-configured curtailment sequence. On the residential side, home automation technologies and smart electricity meters will facilitate demand response from a large number of participants with small load. Another opportunity for demand response is the penetration of electric vehicles. Once integrated with home automation systems, electric vehicles can serve as distributed energy storage to enable more demand response from residential customers.

Energy aggregators Third-party aggregators enlist end users to participate in demand response curtailment and sell the combined load reduction to utilities and independent system operators. Executed properly, demand response aggregation programs spread the risk; load that is not curtailed from sites that opt out can be made up for by other facilities' participation. This aggregation also improves the financial outcome. Since demand response aggregators can almost guarantee to the utility the aggregated curtailment volume resulting from combining load across multiple buildings, the value is greater, which benefits the customer.

4. Distributed Energy Storage

4.1 Introduction

Energy storage is typically categorized based on the form of energy being storage, including thermal, mechanical, chemical, electrochemical, and magnetic, summarized in Table 10.[4]

Table 10. List of energy storage systems that are commercially available

Classification	Technology	Advantage	Disadvantage
Thermal	Chilled water tank	Can use existing chillers, High Capacity, Cost	Weight, location and space requirements, Continuous

[4] http://www.energystorage.org/energy-storage/energy-storage-technologies

		effective in larger systems[5]	maintenance
	Electrical heating with thermal storage	Cost savings, Improved efficiency, Reduced servicing and maintenance cost	Energy losses, Improper sizing[6]
	Molten salts	Efficient, High Dispatchability, High Operating time	Spillage, High Complexity, No modularity, Effort and time for development, validation[7]
	Phase change materials including ice storage	Reduced thermal energy storage space , Colder supply water temperatures, Increased operational flexibility[8]	Low energy efficiency, Poor thermal conductivity of ice
Mechanical	Pumped Storage	High Capacity, Low Cost	Special Site Requirement
	Compressed Air Energy Storage (CAES)	High Capacity, Low Cost	Special Site Requirement, Need Gas Fuel
	Flywheels	High Power	Low Energy Density
Chemical	Hydrogen Storage	High Efficiency	Low Energy Density, Cost
Electrochemical (Battery)	Metal-Air	Very High Energy Density	Difficulty in Electric Charging
	Sodium Sulfur (NaS)	High Power & Energy Densities, High Efficiency	Production Cost, Safety Concerns

[5] http://www.pdhonline.org/courses/m145/m145content.pdf
[6] http://www.house-energy.com/Heaters/Electric-Storage.htm
[7] http://www.dlr.de/sf/Portaldata/73/Resources/dokumente/Soko/Soko2011/K_Wieghardt-Salzturm.pdf
[8] http://www.districtenergy.org/08CoolingConference/Proceedings/2A3_RUGEL_%20Ice_%20Storage_Innovations.pdf

	Lithium ion (Li-ion)	High Power & Energy Densities, High Efficiency	High Production Cost, Requires Special Charging Circuit
	Nickel cadmium (Ni-Cd)	High Power & Energy Densities, Efficiency	High Production Cost
	Other Advanced Batteries	High Power & Energy Densities, High Efficiency	High Production Cost
	Lead-Acid	Low Capital Cost	Limited Cycle Life when Discharged
	Flow Batteries	High Capacity, Power and Energy Ratings	Low Energy Density
Magnetic	SMES (supermagnetic)	High Power	Low Energy Density, High Production Cost
Electric Field	E.C. Capacitors	Long Cycle, Life, High Efficiency	Low Energy Density

Energy storage systems can also be differentiated by location as they can be placed at any of the five major subsystems in the electric power system: generation, transmission, substations, distribution, and final consumers (i.e., behind-the-meter). Figure 6 summarizes the different types of services that an energy storage system can provide at specific subsystems. It is worth noting that electric vehicles can be treated as a form of behind-the-meter energy storage, even though their primary functionality is to provide electrified transportation.

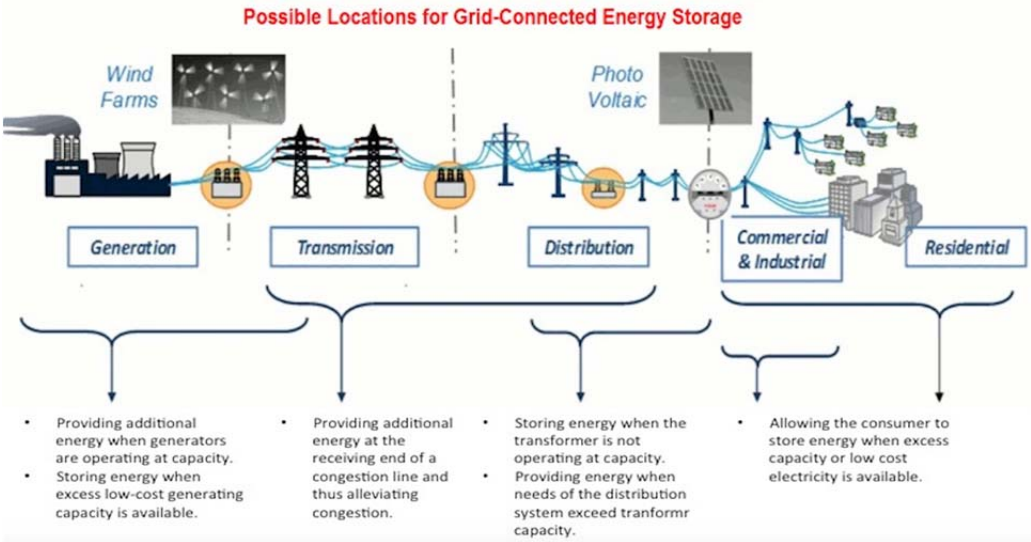

Figure 6: Different locations for energy storage system[9]

[9] http://www.sandia.gov/ess/images/ES-Select1.gif

Important factors to consider when choosing a storage system are capital costs, energy, power, efficiency, and lifetime. Figures 7 and 8 below compare the different technologies in terms of these variables.

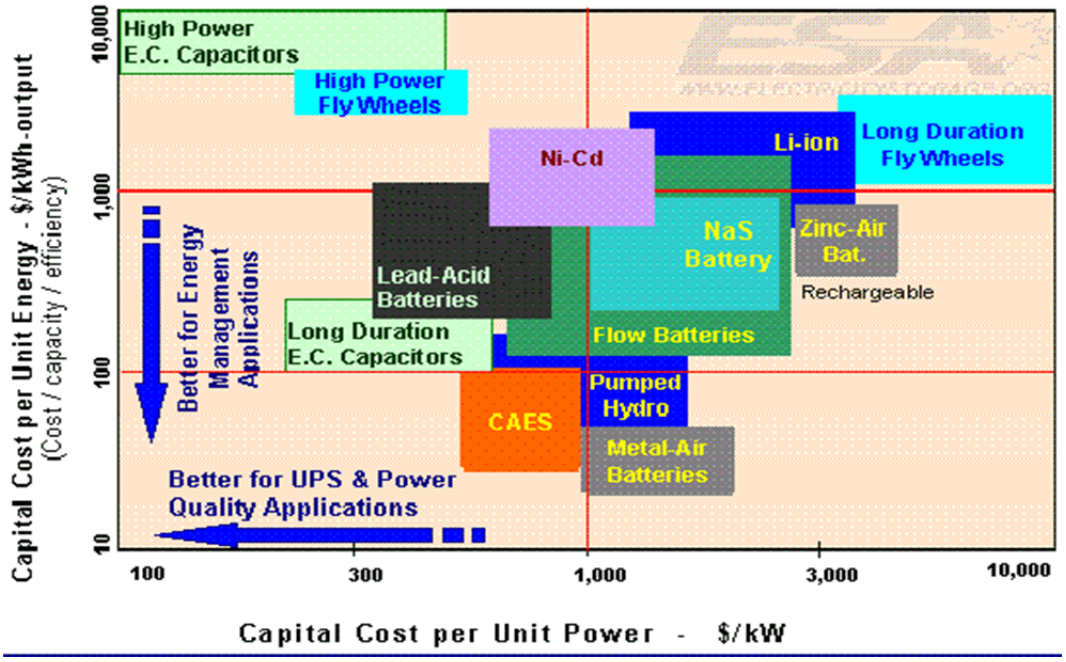

Figure 7. Capital Cost per Unit Energy vs. per Unit Power (Energy Storage Association)

Figure 7 illustrates storage technologies according to their capital costs, power rating, and energy rating, in dollars per kilowatt ($/kW) and dollars per kilowatt-hour ($/kWh). Capital and operating costs, in addition to technical capabilities are key factors used to determine the financial viability of the storage technology.

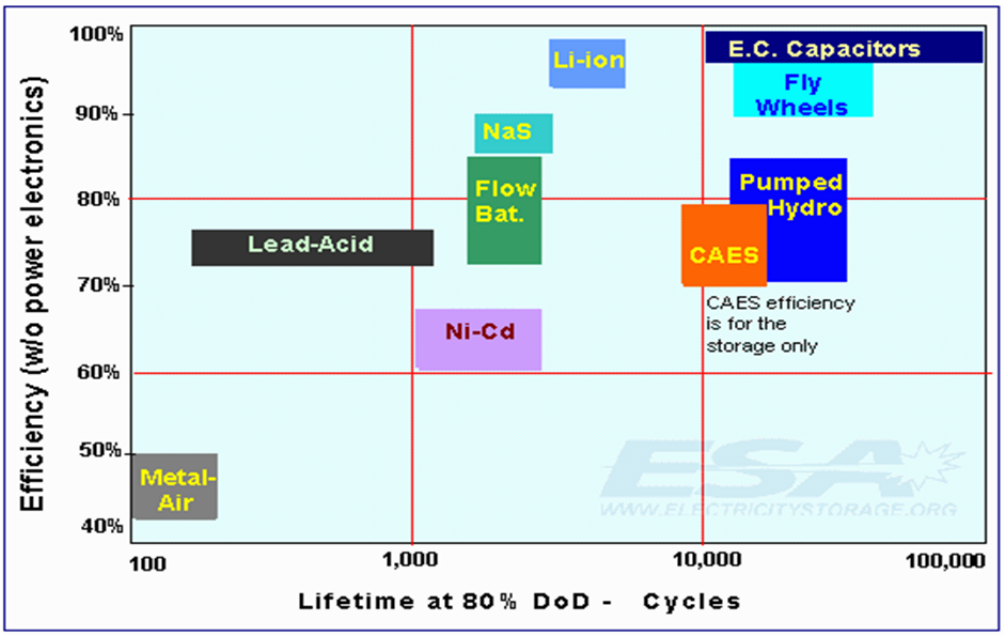

Figure 8. Efficiency and Lifetime (Energy Storage Association)

Figure 8 illustrates the efficiency and lifetime of energy storage technologies. Cycle life refers to the number of charge and discharge cycles that a storage device can provide before performance decreases.[10]

4.2. Potential for Energy Storage

4.2.1 Thermal Storage

Cooling with Thermal Storage Since 1991, Cornell University has operated a thermal storage tank, consisting of 4.4 million gallons of stratified chilled water. This thermal storage tank provides about 30-40,000 chilled water ton-hrs, varying according to temperature changes. The tank was designed to provide a peaking displacement of about 8,000 tons using 59 degree F water.[11] It displaces 5,000 kW in chiller power from daytime to nighttime. Cornell's thermal storage tank system won an ASHRAE Technology Award in 1992[12]. Currently, there are no other thermal storage systems in Tompkins County. For customers with large HVAC load, deployment of ice storage could be cost-effective as ice storage stores energy in form of latent heat (rather than sensible heat as in chilled water storage) and thus occupies less space.

Electric Heaters with Thermal Storage All habitable rooms in Gun Hill Residences, an apartment complex near Cornell campus, are equipped with electric heaters with a highly insulated storage core of dense ceramic material, which can store heat during off-peak hours and release heat when needed. Those electric heaters have been serving the residents with no major problems since late 1980s when the apartment complex was first built. Paying Time of Use (TOU) rate, the heating costs for residents in in Gun Hill Residences are typically similar to those living with natural gas heating. Gun Hill Residences' practice shows the cost-effectiveness of electric heating with thermal storage, which sets an example for the community when considering electric heating.

Electric Water Heaters Water heaters have been used for decades as simple load control devices by many utilities. Commercial products exist to charge water heaters to higher temperatures ("supercharging water heaters"), and use a blending valve to deliver normal hot water temperatures, which essentially turn electric water heaters into thermal storage.

Potential Applications of Thermal Storage Thermal storage can play an important role in achieving the greenhouse gas emission goal in the County. Integrating solar PV with hot thermal storage allows the solar energy to be used later. Air conditioning load is responsible for most of the peak use during the summer. Combing air conditioners with ice storage can effectively shift cooling demand to off-peak time, or match building-mounted solar PV generation with the system peak. The control of supercharging water heaters will enable the grid operator to manage electric water heating loads and use the storage capacity to provide power system services.

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[10] http://www.ny-best.org/sites/default/files/resources/KEMA%20Report%20for%20CDA%20US%20Storage%20Mrkt%202-3-12.pdf

[11] Lanny Joyce, http://www.engr.psu.edu/ae/faculty/bahnfleth/energy_use_in_district_cooling.pdf

[12] http://energyandsustainability.fs.cornell.edu/util/cooling/production/thermal.cfm

4.2.2 Mechanical Storage

The three types of mechanical storage commercially available are pumped hydroelectric storage, compressed air energy storage, and flywheels.

- A pumped hydroelectric energy storage system pumps water to a higher altitude where it is stored as gravitational potential energy. In order to convert the stored energy back into electricity, water is released and passed back through a turbine to a lower reservoir. Having cost-effective storage facility can greatly facilitate the transitioning to a renewable future. The island of El Hierro (one of Spain's Canary Islands off the coast of Africa) is powered entirely by wind and pumped storage hydro [107]. A local site near the Cayuga power plant has been discussed for a potential pumped storage hydro facility, but a detailed feasibility analysis is out of scope for the energy roadmap. The key to quantify the potential is to couple surface topology (to build ponds or locate existing ponds) and elevation changes. However, acquiring the permits to build the penstock and upper reservoir (avoiding wet lands, and deeded property) and the permit to move that volume of water under the current regulatory environment would be difficult.
- In compressed air energy storage, a large tank is buried underground. During times of low external electricity demand, electricity is used to compress air in the tank. During times of peak electricity demand, compressed air is released, heated with natural gas, and forced through a turbine to generate power[13]. NYSERDA's study on compressed air energy storage revealed that this technology may have a huge potential in Tompkins County.[14] It is the most financially attractive when a system provides sufficient power output and sufficient storage time. The Cargill Deicing Technology Cayuga Mine in Lansing may be an area to explore for application of compressed air energy storage, as it encompasses a thick, regional sandstone reservoir. Tompkins County has inactive mines, which may have an appropriate geological structure and are not too far from electric transmission infrastructure.
- Flywheels are charged using an electric motor to capture energy in a rotating mass. An electric generator then can extract the energy when needed. Because of their low energy density and short discharge time, flywheels cannot store enough energy to meet long duration energy demands.

4.2.3 Electrochemical Storage

The largest group of technologies for stationary applications is electrochemical storage. Electrochemical storage can efficiently store electricity in chemicals and reversibly release it when needed. The lead-acid battery has dominated market share in the past century. However, lead-acid batteries are sensitive to temperature and environmental conditions. Considering Tompkins County's long and harsh winter, design changes would need to be sensitive to this important aspect. Developers claim that their lithium-ion batteries will be the solution to long-duration energy storage and could provide energy to help regulate the power grid during times of high demand. It is already the dominant battery chemistry for consumer electronics and electric vehicles. The 1,000 MW projects under development would be capable of providing energy for two hours at less than

[13] http://spectrum.ieee.org/energywise/energy/the-smarter-grid/compressed-air-energy-storage-makes-a-comeback

[14] NYSERDA , *Compressed Air Energy Storage Engineering and Economic Study*,2009. http://www.nyserda.ny.gov/-/media/Files/Publications/Research/Electic-Power-Delivery/compress-air-energy-storage.pdf

$1000/kW, less expensive than a gas-fired power plant.[15] Furthermore, in the beginning of 2015, Eos commercialized a MW-scale Aurora (battery storage) system, employing zinc hybrid cathode battery technology, enabling low-cost electricity storage and long life.[16] Their simplicity of design and use of inexpensive materials contribute to the low-cost manufacturing models, making these batteries cost competitive. Microgrids can utilize energy storage for clean and reliable power, integrating renewable energy with the grid to provide increased security, and operational capabilities. In San Diego, CA, Princeton Power System provides an energy storage system for Scripps Ranch, consisting of two Grid-tied Inverters and a 100 kWh lithium-ion battery rack.[17] The system is connected to a 30 kW PV array, from which the storage system collects power to store energy. During a power outage, the batteries and PV array provide backup power to the facility.

4.3 Challenges and Opportunities for Energy Storage

4.3.1 Energy Storage R&D in the Southern Tier Region

The following centers conduct research in energy storage technologies.

Table 11. Energy Storage Research Centers in the Southern Tier Region

Name	Location	Description
Energy Materials Center at Cornell (EMC^2)	Cornell University, Ithaca, NY	R&D of energy conversion, storage, and properties of active materials and their interfaces
KAUST-Cornell Center for Energy and Sustainability (KAUST-CU)	Cornell University, Ithaca, NY	Investigating organic-inorganic hybrid nanomaterials for applications in energy storage[18]
NorthEast Center for Chemical Energy Storage	Binghamton University, Binghamton, NY	Research in the design of lithium batteries, developing an understanding on key electrode reactions in order to improve electrochemical performance. Awarded $12.8 million by Department of Energy to fund Energy Frontier Research Centers[19]
New York Battery & Energy Storage Technology	New York State	Testing, validation and independent certification of

[15] http://www.greentechmedia.com/articles/read/AES-Betting-on-Lithium-Ion-Batteries-For-Long-Duration-Energy-Storage
[16] http://www.forbes.com/sites/chipregister1/2015/01/13/the-battery-revolution-a-technology-disruption-economics-and-grid-level-application-discussion-with-eos-energy-storage/3/
[17] http://www.rpi.edu/cfes/Workshop%20on%20Microgrid/B3%20-%20Martin%20Becker%20-%20Priceton%20Power%20Systems.pdf
[18] https://kaust-cu.cornell.edu/
[19] http://www.newswise.com/articles/binghamton-university-receives-12-8-million-for-innovative-energy-research

Consortium (NY-BEST)		diverse forms of commercial energy storage

4.3.2 Hydrogen Storage

The creation of a hydrogen filling station in Ithaca, and the addition of a hydrogen fuel-cell bus were recently considered by Tompkins Consolidated Area Transit (TCAT). In 2013, the U.S. Department of Transportation allocated $13.6 million to promote fuel cell technology in U.S. transit buses. TCAT got selected to receive one of the three demonstration hydrogen fuel-cell buses in late 2014and Standard Hydrogen Corporation, has slated to partner with Cornell University to build the hydrogen filling station. However, due to a number of factors this project has been terminated. An advantage of hydrogen vehicles is that one fill-up would then allow the vehicles to run for 300 miles, before the next recharge. A hydrogen station would convert water to hydrogen and oxygen by using electricity from renewable sources and has the capacity to support 10 to 15 fuel cell cars a day[20].

4.3.3 Zinc Battery Manufacturing in Ithaca, NY

In 2013, Eos Energy Storage partnered with Incodema, an Ithaca based prototype manufacturing and full service rapid prototyping company, to produce a MW-scale low-cost zinc hybrid cathode battery technology. Eos chose to partner with Incodema, because their innovative battery enabled a scalable, low-cost, production process. This technology presents enormous opportunities for electrochemical storage. It addresses the most common challenge among battery manufacture, which is the high capital costs.

4.3.4 Economics and Environmental Impacts

Some challenges facing energy storage are universal to all storage types. Power densities (W/kg or W/litre) are still not high enough to balance the intermittent supply of renewable energy in large capacities given a limited operating space. Other notable constraints to storage in general are the high capital, operating and maintenance costs, as well as energy losses in self-discharge, rigid response time, recycling of materials, and safety issues [31]. In 2014, the Department of Energy developed a Strategic Plan ensuring energy storage safety and reliability. Essentially a roadmap for grid energy storage safety, the Plan addresses the range of utility, community and residential energy storage technologies being deployed across the Nation. It highlight safety validation techniques, incident preparedness, safety codes, standards, and regulations. As energy storage has a long term potential, it makes a list of recommendation for near- and long-term actions.[21]

4.3.5 Related Policies: Energy Storage Mandate in California and REV in New York

In October 2013, the California Public Utilities Commission (CPUC) established an energy storage target of 1,325 MW by 2020 for the state's big three investor-owned utilities, namely Pacific Gas and Electric Company, Southern California Edison, and San Diego Gas and Electric, with installations required no later than the end of 2024.

[20] http://www.emc2.cornell.edu/news/story/new-ithaca-company-seeks-to-showcase-hydrogen-powered-vehicles.html

[21] http://energy.gov/oe/downloads/energy-storage-safety-strategic-plan-december-2014

One of the central components of the New York State Public Service Commission's Reforming the Energy Vision (REV)project is the concept of the utility as a Distributed System Platform Provider (DSPP). Under REV rather than setting a specific numeric target (as in California), the Distributed System Platform Provider (DSPP) in conjunction with market participants will identify economic applications of storage, including, facilitation of clean intermittent generation. The utility as a DSPP is one of the central components of the REV vision.

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[22] http://energy.gov/energysaver/articles/estimating-appliance-and-home-electronic-energy-use

[23] http://www.fueleconomy.gov/feg/evtech.shtml

[24] http://www.teslamotors.com/goelectric/efficiency

[25] http://www.fueleconomy.gov/feg/evtech.shtml

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[29] http://www.cpuc.ca.gov/NR/rdonlyres/71859AF5-2D26-4262-BF52-62DE85C0E942/0/CPUCStorageWhitePaper7910.pdf

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Appendix

Rental Properties Case Study: South Hill Outreach for Rental Experience

2.2.1 Background

In rental properties, tenants do not have the motivation to save energy if utility bills are paid by the landlord (i.e. gross leases), or to upgrade the energy system if they do have to pay the bills (i.e. net leases) but the lease term is shorter than the payback from energy saving. In this latter case, landlords do not have the incentive to invest in the upgrades either because the tenant is paying the bills [37]. Such split incentives, a.k.a. landlord/tenant dilemma, is particularly striking in the City of Ithaca where 73% of the housing units are student rentals [38].

Thanks to Ms. Anne Rhodes from the Cornell Cooperative Extension (CCE)-Tompkins County, we were able to know about a successful pilot project, South Hill Outreach for Rental Experience (SHORE), that significantly increases energy efficiency in rental properties.

2.2.2 Project Setting

Four major parties partner in this project. Ithaca College (IC) runs an off-campus housing lottery system, which is a critical incentive factor behind the project design. First years are required to live on-campus. Off-campus housing availability for other students is decided by lottery. Attendance at CCE-Tompkins' workshops about energy efficiency and getting high scores in the following quizzes increase one's chance of winning the lottery. At the same time, leadership training is a mandatory section in IC students' graduation structure. Concerned about energy efficiency in on-campus dormitories, one main topic of IC's leadership training is energy efficiency. Other topics IC students can choose from include transportation safety, waste management, and healthy food.

CCE-Tompkins is the project coordinator and provides a four-year education program about energy efficiency to IC students. As part of the leadership training, program takes place as workshops and quizzes, and is required in students' first year, while voluntary in their rest years in college. There are a number of

collaborators to implement the education program, including Res Life, Peer Educators, Landlords, and the Neighborhood Association.

In addition, PPM Homes is a rental properties complex where IC students gather off-campus. And NYSEG provides utility data of PPM Homes.

2.2.3 Mechanism

The driving mechanism behind the project includes net lease, flex lease, and cash rent rebate. Net lease indicates that students pay for their utility fees separately from rent. Monthly meter readings are compared with the energy use benchmark, which is the respective PPM unit's past two academic years' utility statistics provided by NYSEG. The gain in energy saving is accrued in terms of cash, which is rebated to students at the end of each academic year, i.e. the flex lease and cash rent rebate.

2.2.4 Future Development of Incentives

Indeed, SHORE is an exemplary project. Yet many more developments to it are expected to be carried out. From the students' side, enhanced energy use behaviors will be certified to build trusts between landlords and students. The trust can better motivate landlords to upgrade their energy systems.

From the landlords' side, they are advocated to make up-front energy retrofits to reduce EUI of their houses, which can be an attractive feature in the rental market. Rent premium may be charged to recoup the investments, yet relevant regulations should clarify the amount of premium that is allowed, so that tenants are protected and can benefit as well from the energy savings and reduced utility bills in net leases. It is also important to help landlords form a concept that energy retrofits to reduce consumption is the right thing to do.

From the utility companies' side, stronger requirements and incentives to energy efficiency programs from the New York State Public Service Commission via its Energy Efficiency Portfolio Standard [52] are expected. NYSEG has just launched a new energy efficiency program - Blocking Bidding - in October. Based on specific qualification requirements, "The Block Bidding program is a sealed-bid, pay-as-bid auction. … Through the Block Bidding program, NYSEG purchases 'blocks' of electricity savings representing reduced electric usage- from eligible commercial, industrial and municipal customers or from third parties (aggregators) working with those customers." [53] In other words, hopefully NYSEG will become a primary payer for energy savings in more projects like SHORE in the County.

From the rental market, a website is intended to be built that broadcasts each rental unit's energy use information, in order to regulate the market towards having a more energy-conscious operation. And increasing the accommodation capacity is crucial to increasing market competition and reducing rents, which may make the feature of energy efficiency outstanding and a profitable asset. For example, three new large rental properties in downtown will soon be completed. They will receive property tax abatement for a certain period of time from the City of Ithaca through the Community Investment Incentive Tax Rebate Program, in order to keep their rents down and make the rental market more competitive [59].

From the policy context, a customized building code, which specifies energy settings in existing houses more stringent than the original version for NYS, will take effect in the County in January 2015. A detailed criteria and grading manual to enforce the codes is needed and is under development. Local code officers will be trained to follow the manual and enforce the codes. Local or state level financing programs that help reduce upgrade costs specifically in rental properties are also absent but desirable.

As mentioned at the beginning of this section, key to more general practices of similar projects is to find the right motives for behavior changes in both landlords and tenants. The motives may include reduced utility bills in net leases for tenants, and a market that emphasizes features of energy efficiency for landlords.

Focus groups are doing surveys in East Hill and Cornell to find out occupants' current energy use behaviors, what they think about their behaviors, and what incentives can motivate behavior changes. Results are expected to come out by December 2014. Hopefully, the findings, together with the experience gained in SHORE will guide the development of successful energy efficiency projects in more rental properties in the County.