Draft Environmental Impact Statement

Energy Recovery Linac (ERL) Project

Cornell University

Town of Ithaca, New York

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Draft
Energy Recovery Linac (ERL) Project

Cornell University
Town of Ithaca
Tompkins County
New York
Submitted: XXXX

Lead Agency:	Town of Ithaca Planning Board Town of Ithaca 215 North Tioga Street Ithaca, NY 14850
Contact Person:	Susan Ritter, Director of Planning T: 607-273-1747
Prepared By:	Trowbridge & Wolf, LLP 1001 West Seneca Street, Suite 101 Ithaca, NY
Contact Person:	Kimberly Michaels, RLA, LEED AP, Principal T: 607-277-1400
Developer:	Cornell University Ithaca, New York 14850
Contact Person:	David Rice, Technical Director, Wilson Laboratory T: 607-255-8786

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Cornell University's Climate Action Plan

In 2007, President David Skorton signed the American College and University Presidents' Climate Commitment (ACUPCC) pledge, directing the University to pursue climate neutrality. As stated on the ACUPCC website (http://www.presidentsclimatecommitment.org), "climate neutrality is defined as having no net greenhouse gas (GHG) emissions, to be achieved by minimizing GHG emissions as much as possible, and using carbon offsets or other measures to mitigate the remaining emissions." GHGs are gases in the earth's atmosphere that absorb radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect.

Because greenhouse gas (GHG) emissions are ultimately tied to fossil fuel energy use, this pledge required a comprehensive energy planning study for Cornell's future. Ultimately, Cornell sought a plan which would replace fossil fuels with renewable and non-fossil resources for heating, cooling and powering the campus.

Cornell's Climate Action Plan (CAP) is a comprehensive response to the challenge for a carbon-neutral future. It was created with financial support from the New York State Environmental Research and Development Authority (NYSERDA) and technical support from a team of consultants led by Affiliated Engineers, Inc. and Energy Strategies, Inc. The CAP analysis and recommended actions are specific to Cornell. Broad planning initiatives on campus including the Campus Master Plan (CMP) and the transportation-focused Generic Environmental Impact Statement (t-GEIS) are foundational documents for the CAP. The CAP reflects Cornell's unique energy operations as well as the university's specific research and teaching needs.

The CAP provides a pathway for a carbon-free future featuring the complete elimination of net greenhouse gas (GHG) emissions required to heat, cool, and power the Ithaca campus by the year 2050. This goal is not only a response to urgent environmental imperatives but also recognizes and seeks to minimize the substantial financial risk posed by uncertain future fossil fuel costs and carbon emissions.

The CAP recommends 19 specific actions which, if successfully implemented, would allow Cornell to achieve climate neutrality. These actions, derived from the contributions of hundreds of ideas generated through a community-wide effort, are categorized into five Action Wedges.

- Green Development: the implementation of future development in a manner that minimizes GHG impacts of development
- Energy Conservation: the reduction in energy use for existing operations
- Fuel Mix and Renewable Energy: the replacement of high-carbon fossil energy use with energy that is carbon-free or produced lower GHG emissions per unit
- Transportation: the reduction in GHG emissions related to the University's business and commuter travel
- Offset Actions: the implementation of actions outside the University boundary that lower global GHG emissions

An illustration of Cornell's GHG reduction goals though use of these "wedges" is provided in Figure 1.10.b. In addition to the five wedges listed above, the illustration includes a "Beyond Coal" wedge, which represents the GHG savings associated with the decision to end the use of coal at Cornell beyond 2011.

In Figure 1.10.b, the vertical axis is in units of "Metric Tons Equivalent of Carbon Dioxide (MT CO_2-

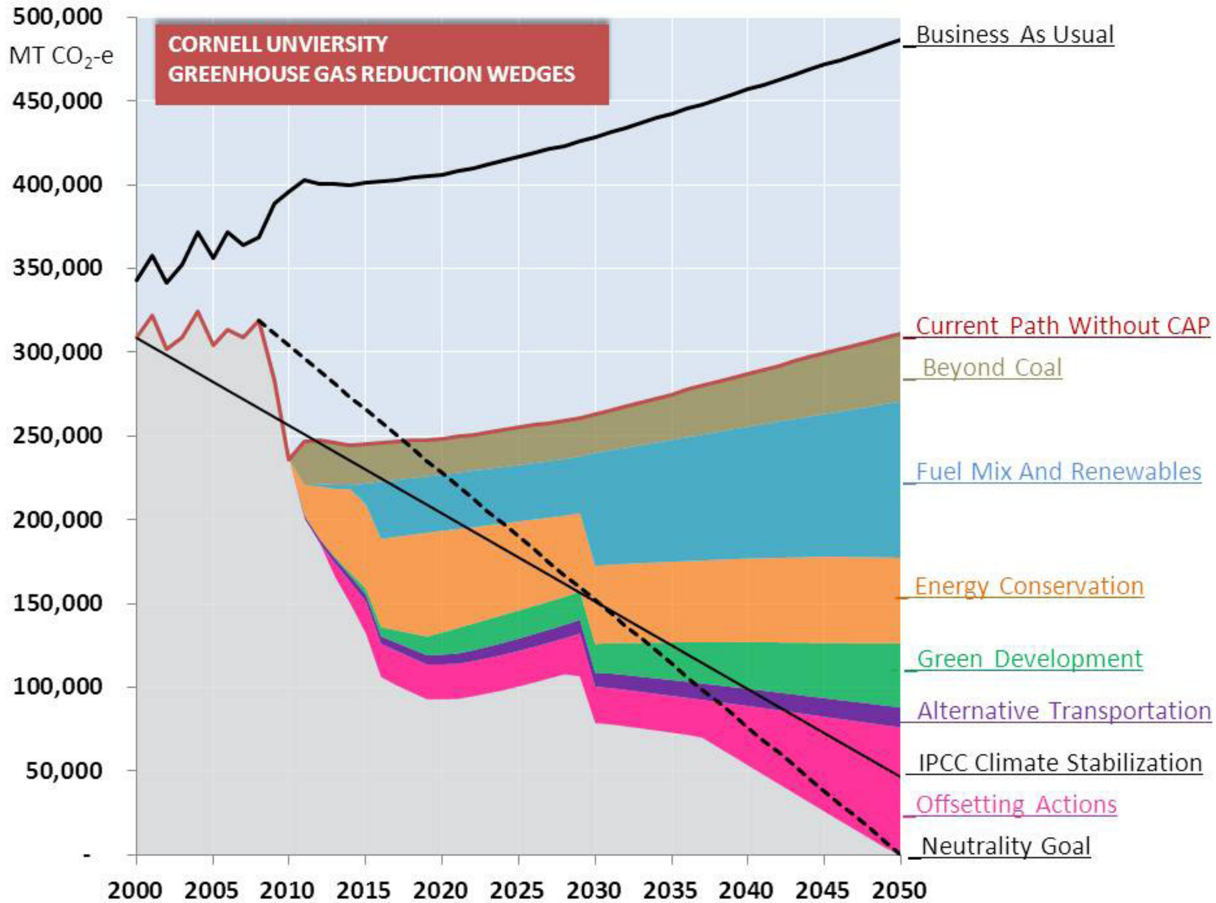

Figure 1.10.b: Cornell University Greenhouse Gas Reduction Wedges

eq). A further explanation of the estimate process, the units, and the full climate action plan is available online: http://www.sustainablecampus.cornell.edu/climate/.

The CAP does not impose limits on the rate of campus development or the type or nature of future academic programs. Rather, the CAP supports planning goals and the University's core mission of academic excellence which includes teaching, research and outreach while simultaneously changing the process by which energy is used in the future. The CAP specifically took the future ERL into account during the modeling of alternative future scenarios for energy use and sources. While the ERL will increase the electrical needs of campus, it will not change the principles of the Climate Action Plan or interfere with the goals for reaching climate neutrality. Rather, the CAP was specifically designed to acknowledge the vital need for research and teaching and accommodate those needs in future energy and GHG forecasting and planning.

The technical analysis used in the CAP is designed to be periodically updated and, as such, the CAP is considered a living document. As projects are funded and integrated into campus plans, the CAP will reassess specific technologies and adjust short-term technology choices or scales to accommodate improved growth models and projections, with long-term goals remaining intact. For example, Cornell's 2010 decision to eliminate coal use on campus a full decade in advance of CAP targets has changed the University's projections of carbon emissions, creating earlier reductions than planned. In a similar manner, all future decisions and developments will impact future CAP technology assessments.

Specific goals and programs included in the CAP have been integrated into the development of the ERL project. Some examples of this integration are:

- Site selection and layout: The CAP supports the re-use of existing facilities as part of new development as a means to reduce development costs. The layout of the proposed ERL project reflects the University's goal of creating compact future development while accommodating needed academic development. This strategy corresponds to the CAP action "Improved Land Use", which is part of the Green Development wedge.
- Parking and transportation infrastructure: The site can be accessed through existing transportation infrastructure, reduces on-site parking and retains and enhances pedestrian/ bicycle facilities. This strategy supports the Commuter Travel action within the CAP's Alternative Transportation wedge.
- Energy use: While researchers worked to reduce the energy use of the ERL process itself, building and site designers have designed the proposed project to re-use heat energy, which is typically wasted, to heat the East and West additions and Cryogenics Plant. This philosophy of using energy twice mimics the central Combined Heat and Power philosophy for the campus as a whole. These energy goals are reinforced through the use of the Leadership in Energy and Environmental Design (LEED) process for the laboratory building expansion. LEED requires the detailed assessment and documentation of energy use, reviewed by third-party energy experts. Section 1.8 provides more details on the LEED goals for this project; Section 2.12 addresses energy impacts. The reduction in energy use for the laboratory and office facilities, compared to typical code-compliant buildings, follows the recommendations of the Building Energy Standards CAP action, another part of the Green Development wedge.
- Energy Research: The energy directly utilized by Cornell is only a small fraction of the potential global energy reductions possible through effective energy education, research, and outreach. The ERL will support research that is broadly applicable to renewable energy systems including better solar cell optimization, creating more efficient fuel cell materials, and combustion process improvements, all of which have the potential to create significant, permanent improvements beyond the campus boundaries. Sections 1.1.3, 1.1.4 and Appendix A provide more details on the science and potential of the ERL project. Energy research is essential to the Offsetting Actions wedge of the CAP.

In summary, the CAP does not impose specific development restrictions but provides a framework to guide future development in ways that promote the objective of a future carbon neutral campus. The ERL is consistent with the CAP goals of advancing vital education and research while minimizing the GHG impacts of the energy used for that work.

2.12 Energy Impacts

2.12.1 Power Consumption

The terms energy and power are frequently interchanged, but they represent distinctly different quantities. Power describes the rate at which energy is consumed or generated. Energy is the measure of how much power has been consumed over time. One way to illustrate the difference between power and energy is to envision a hose filling a pool with water. The rate at which the water comes out of the hose is equivalent to the measure of power. The amount of water necessary to fill the pool is equivalent to the measure of energy. The greater the rate of water flowing from the hose (power), the shorter the time it will take to fill the pool (energy). Power times time equals energy.

Units of electrical power are typically measured in kilowatts (kW). One kilowatt is one thousand watts. Units of electrical energy are measured in kilowatt-hours (kWh). Watt-hours are used to describe the amount of energy used over time. For example, a 100 watt light bulb needs 100 watts of power to operate, and a 60 watt light bulb needs 60 watts of power to operate. Over the course of two hours, the 100 watt bulb will consume 200 watt hours of energy, and the 60 watt bulb will consume 120 watt hours of energy.

Energy sources other than electric (steam, chilled water, gas) each have their own units of measure. There are constants to convert energy between units of measure. These constants, when used with the efficiencies of conversion between these energy forms, may be used to compare or sum energy use on a common basis. Energy conversion efficiencies are often measured by Coefficient of Performance (COP). For example, an air conditioner uses one kW of electric power to provide an effective two kW of cooling. This air conditioner would have a Coefficient of Performance of approximately 3 (COP=3). Since electricity is the major source of energy used for both the present Wilson Laboratory operation and the planned ERL operation, we will use million watt-hours (megawatt-hours or MWh) for all energy use discussed in this section and megawatts (MW) for power.

A. Existing Conditions

Electrical energy represents the largest component of energy use at Wilson Laboratory. The energy use of the existing particle accelerator has varied from year to year dependent on the educational research operations during each annual period. The following is a summary of the electricity use per year in units of MWh. The second row of data represents the total electrical energy use of Cornell's Ithaca campus, and the last is the ratio of Wilson Laboratory to Cornell's electrical energy use.

Cornell Fiscal Year (July 1)	**FY10**	**FY09**	**FY08**	**FY07**
Wilson Electric Energy (MWh)	26,313	22,780	27,903	28,328
Cornell Electric Energy (MWh)	243,500	242,800	249,900	245,700
Wilson fraction of Cornell	10.8%	9.4%	11.2%	11.5%

Table 2.12.a: Wilson Laboratory and Cornell Energy Use

The Wilson particle accelerator, the largest science instrument on campus, requires more electrical energy than any other single campus facility, representing roughly 11 percent of current campus electricity use. The annual energy use at Wilson Laboratory is primarily for operation of synchrotron components (55 percent), followed by the cryogenics plant (23 percent), with the balance (22 percent) for building utilities. The power used varies between standby and operational conditions. The standby power needs of the current system, including both the cryogenics equipment and other operations and building systems, is approximately 1.1 MW (based on 2009 operations data). The current synchrotron system, when operating, utilizes a peak power level of four to five MW during typical research-intense periods.

While electricity comprises the majority of energy usage at Wilson Laboratory, the facility also uses campus steam and natural gas to heat the building in winter and campus chilled water (Lake Source Cooling) to cool the building in the summer and to cool some equipment systems. The table below summarizes Wilson Laboratory's heating and cooling requirements in recent years and compares total energy with the overall campus. Energy use for all sources has been converted to units of MWh/year using nominal conversion factors between energy units and taking into account the Coefficient of Performance (COP) of the sources. The heating needs per unit area of Wilson Laboratory are substantially lower than similar buildings on campus, primarily due to concomitant effects of recycled heat from equipment. The energy needed to cool Wilson Laboratory is small compared to off-campus buildings because of the high COP of lake source cooling.

Energy Source	**FY10**	**FY09**	**FY08**	**FY07**
Electric	26,313	22,780	27,903	28,328
Electric for Cooling (chilled water)	459	332	365	355
Heating (steam)	675	697	1,390	1,372
Heating (gas)	312	324	281	273
TOTAL	**27,760**	**24,133**	**29,939**	**30,329**
Fraction of Cornell total energy use	**3.6%**	**3.3%**	**4.1%**	**4.2%**

Table 2.12.b: Wilson Laboratory Energy Use in MWh Per Year Electric Equivalent

In 2009, Cornell self-generated approximately 10 percent of the electricity used on campus using its run-of-river hydropower plant and steam turbine generators, which convert excess steam pressure to electricity plus delivery-pressure steam. The remainder of the electricity was purchased from the regional energy transportation company, New York State Electric and Gas (NYSEG), and delivered to campus via two 115 kV power lines that feed Cornell's Maple Avenue substation.

Cornell has recently (2007-9) expanded and modernized its central utilities, which included installation of a combined heat and power natural gas combustion turbine system (CCHPP). The turbine system became operational in late 2009 and is sized to provide a power output of about 30 MW (15 MW each for two units). In addition, the campus system continues to use the hydroelectric plant (about two MW) and the existing steam turbine generators (six to seven MW) for a total of eight to nine MW of additional electric power. All together, the campus on-site generation capacity beginning in early 2010 was almost 39 MW. This exceeds the current campus electrical needs, so that Cornell has the capacity to generate more power than required for campus operations most of the time. Because only one CCHPP turbine is operated in summer months, Cornell estimates it will generate a net of over 80 percent of the electricity used on campus each year, while purchasing the remainder from the local grid. Cornell expects that one CCHPP turbine, the existing cogeneration system, and the hydroelectric plant will operate for nearly all of the year. In addition the second CCHPP turbine will operate for nine months of the year. Under these conditions Cornell will produce approximately 290,000 MWh per year.

As a backup, the campus continues to be connected to grid power through two independent 115 kV NYSEG utility feeds. Three 27 MW transformers are available to feed the 13.2 kV campus distribution system.

B. Project Impacts on Energy Use

The ERL will be the first scientific instrument to provide extremely high power density continuous x-ray beams. It will be the only instrument of its kind in the United States. For the foreseeable future it provides a unique opportunity for scientists to do research not possible elsewhere.

The proposed project will require electrical power at two levels. The base operational power level will provide for normal building utilities, (HVAC, lighting, and routine laboratory activities) as well as for the Cryogenics Plant to maintain the liquid helium. Operation of the ERL will require an additional level of electric power.

During operations of approximately 5,000 hours per year once fully commissioned, the ERL will require additional electrical energy for two major systems, namely, the particle accelerator and the cryogenics system to create the very low temperature conditions required for accelerator operation. The power needed to operate the beam is estimated at about 6.7 MW for the accelerator and an additional 7.2 MW for the Cryogenics Plant.

The electrical power needed to operate the Cryogenics Plant will range from about three MW at base level to approximately 10 MW during full accelerator operation. In standby condition the Cryogenics Plant provides minimal cooling to keep the helium liquid, while full rated output provides additional cooling needed to efficiently run the ERL. Using the information provided by major equipment manufacturers, together with operating experience and analysis of system needs, scientists at Cornell's Wilson Laboratory have estimated the following annual energy use for the ERL. In the following table "FULL OPERATION" refers to full power operation of the accelerator, "WARM STANDBY" refers to a condition where the support facilities are active but the beam is not turned on, and "STANDBY" refers to the time shutdown for maintenance. All power figures are in MW.

	FULL OPERATION	**WARM STANDBY**	**STANDBY**
TOTAL Cryoplant MW	10.2	4.7	3.0
TOTAL Wilson & new Lab building MW	1.9	1.9	1.9
TOTAL Accelerator MW	6.7	1.58	0
Facility Electrical Power MW	18.8	8.18	4.9
Hours/year	5,000	500	3,260
Annual electrical energy use (MWh)	**114,064**		

Table 2.12.c: Expected ERL Electricity Use in Full Design Operation

These calculations are conservative. The system may be operated at partial power levels for some period with significantly less net energy use. Nonetheless, a rounded estimate of 115,000 MWh of energy per year could be required for future operation of the ERL should full power operation for 5000 hours per year be achieved. This is about 88,000 MWh of electrical energy added to the present Wilson Laboratory annual use.

In the following, the other energy sources used by the ERL are included, although they are small in relation to the electricity use. The architect's report estimates that the peak building cooling requirements of the ERL facility will be 760 tons, corresponding to 110 kW (with lake source cooling). A peak cooling use is assumed for six months to reflect the average over the part of the year where the cooling is needed. Cornell's Lake Source Cooling has a Coefficient of Performance of 25, meaning the actual energy required to provide this cooling is 1/25 of the heat transfer achieved. This sums to 483 MWh/year electrical energy. Add to this 2/3 of the present Wilson Laboratory cooling required = 252 MWh/year. One-third is process water cooling that will not be present for ERL. External heat sources (steam) will be needed only during colder months, and only when the beam is not on since the heat generated during the Cryogenics Plant operation will be recycled for use to heat the buildings. The annual use may be conservatively estimated assuming three months of peak heating per year with 50 percent of required heating from the Cryogenics Plant recovered heat, yielding 4,000 MWh/year effective energy. To this was added 1,000 MWh/year for Wilson Laboratory heating requirements. The table below shows the estimated total annual energy use of the ERL once full design operation is achieved.

Energy Source	**MWh/year**
Electricity	114,092
Electricity for Cooling (chilled water)	735
Heating (steam)	5,000
TOTAL	**119,827**
Existing Facility Use	28,000
ERL additional over existing	91,827

Table 2.12.d: Design Annual Energy Requirements of the ERL

Compared to the 91,827 MWh/year in the Table 2.12.d above, the increase in total energy use by ERL operation is equivalent to 2,565 households. The average total annual energy use by Northeast households (including electricity, fuel oils, liquefied petroleum and natural gases) is the equivalent of 35.8 MWh [2005 data HTTP://www.eia.doe.gov/aer/txt/stb0204.xls].

Several x-ray sources recently built or under construction are shown in the table below. Peak power figures are from publications or correspondence with facility directors. Estimates of annual energy consumption are based on 5000 hours per year of operation and 30 percent of the peak power for the remainder of the year. While these sources' power demands are similar to the ERL, the quality of the beam they produce will be significantly less than that of the proposed ERL.

Facility	Location	Peak Power (MW)	Annual Electric Energy Used (MWh)
NSLS-II Light Source (3 GeV 4th generation)	Long Island, NY	18	112,500
XFEL Light Source (20 GeV 4th generation)	Germany	18	112,500
Linac Coherent Light Source (14 GeV 4th generation)	Menlo Park, CA	11	68,750

Table 2.12.e: Electric Energy Use of Recent Major X-Ray Sources

The ERL project team is currently in discussions with Cornell Utilities, the State of New York, and local energy suppliers to determine the most reliable and cost effective method of providing power to the ERL facilities. The State of New York Power Authority and local energy suppliers have concluded that the infrastructure exists in the local area to provide this future need with no adverse impacts to the local or regional energy supply even in the absence of Cornell-provided power.

C. Mitigation Measures

Given the requirement to maintain the beam quality and intensity to accomplish the research envisioned, several energy saving measures have been incorporated in the ERL design:

1. The energy recovery principle incorporated into the proposed accelerator is 98 percent efficient considering total energy use, an enormous saving compared to producing the same quality beam with a conventional linear accelerator.

2. The accelerator magnets have been specified to use more expensive copper coil material instead of aluminum as well as a larger cross-section, which will save over 400 MWh of energy per year.

3. Based on the current design, the Cornell ERL is currently on track to achieve at least LEED Silver Level Certification, corresponding to significant reduction of carbon footprint.

4. Heat recycled from the Cryogenics Plant will provide most of the required building energy for heating the proposed buildings.

5. The ERL Cryogenics Plant has been designed so that recycled heat could be used in the future at one or more campus facilities.

6. Lake Source Cooling requires 1/25 the energy represented by the needed tons of cooling, effectively saving most of the energy in cooling the building compared to conventional cooling equipment.

Energy use by the ERL would be substantially greater if these actions had not been taken. They are assessed individually in the table below.

Mitigating Action	Description	Annual Energy Savings
1. Accelerator Energy Recovery	Recover beam energy using superconducting RF cavities after production of X-rays	3,752,150 MWh
2. Magnet coils	Use larger copper coils (higher capital cost) to reduce power loss in magnets	400 MWh
3. LEEDNC v.2.2 cert.	LEED certification includes a variety of environmentally sensitive measures that are not easily quantified in terms of energy. At this level a 30% savings in energy is expected.	6,810 MWh
4. Heat recycle (ERL lab)	Assume 25% of the heat rejected from the cryogenics plant during "Full Operation" can be recycled to heat campus buildings.	12,750 MWh
5. Heat recycle (campus)		
6. Lake Source Cooling	Energy savings of LSC's COP=25 compared to air conditioning units with COP=2	8,450 MWh

Table 2.12.f: Energy Savings from Mitigation Measures Incorporated into the ERL Design

The total quantifiable annual energy savings from mitigation measures 1, 2, 3, 4, 5 and 6 is 3,793,310 MWh per year. The contribution of measures 2, 3, 4, 5 and 6 is 41,160 MWh per year, representing a savings of 19 percent relative to ERL energy use if these measures were not incorporated.

Cornell Electrical Infrastructure

The Cornell Utilities Department has installed a new 500 psi natural gas pipeline from the nearby (three miles) Dominion interstate pipeline. While this pipeline currently supplies the two Cornell CCHPP turbines, it was sized to have sufficient capacity to operate a third gas turbine, should Cornell decide to expand the facility in the future. Campus systems are sufficient and adequate to provide support for the ERL project without any major supply system upgrades.

The existing regional systems and major campus switchgear are adequate to provide the power both for the existing campus needs (peak campus load is currently about 34 MW) and for the future growth represented by the ERL project, without Cornell's energy sources. The additional electricity requirements of the ERL will not cause a local electrical energy shortage.

Long Term Energy Impact

While in the short term the ERL will necessarily be a significant user of energy, the expected long term impact is a net world-wide saving of energy orders of magnitude greater. The ERL will be a national research platform. If several ERLs were constructed in each city like shopping malls, the energy impact would be huge. However, it is likely that only one ERL will be built in the United Sates in the foreseeable future. Spread over a geographic area of that size, the energy impact is insignificant. This national research platform will make possible experiments in many technical disciplines, including combustion science, materials science, atomic physics, and chemistry. Many of these applications have energy implications. For example, a brilliant x-ray source may help combustion scientists see the as-now-unseen intermediate steps of combustion chemistry, leading towards an understanding that might yield more efficient combustion processes. Similarly, the ability for materials scientists to see the atomic and molecular structure of new materials and coating systems is expected to lead to advancement in things like thin-film technology, battery materials, and electrical coatings. A brilliant x-ray source can help scientists understand and improve technologies for alternative energy sources.

Due to the large scale of national energy usage any single successful application could result in energy savings that far outstrip the energy consumption of the ERL. For example, a materials improvement that increased computer server efficiencies by, say, half a percent would save 400,000 MWh of energy. The EPA's estimates that today's servers and server cooling systems use at least two percent of the nation's electrical supply (two percent of 4,000,000,000 MWh is 80,000,000 MWh per year; 0.5 percent of savings equates to 400,000 MWh savings). Similarly, even small improvements to alternative energy sources or basic combustion could yield orders of magnitudes higher level savings of energy than that used by ERL.

Such improvement is speculative but not unreasonable. Computer systems today are much more efficient at processing and displaying information than outdated systems, and lighting energy required "per lumen" in the United States has been significantly reduced in the last several decades, thanks to improvements that started with basic research. Similarly, automobiles are being designed today that can double the efficiency of prior designs, without compromising performance.

In summary, the potential positive impact of the ERL on global energy consumption is very large and could greatly exceed the energy used to operate the system itself. The relative local significance of the adverse environmental impact from energy use will be balanced by the local and national societal benefits to be gained from the proposed ERL (See Appendix A).

D. Significant Unavoidable Adverse Impacts

As with many state-of-art major research endeavors, the ERL will be a significant user of energy even after all mitigating steps have been taken. This is a significant unavoidable adverse environmental impact. The existing energy supply is adequate to meet the expected demand and is accommodated in the campus utility infrastructure.

2.12.2 Greenhouse Gas (GHG) Emissions

A greenhouse gas (GHG) is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. This process is a fundamental cause of the greenhouse effect. While a number of gases are considered GHG emissions, carbon dioxide gas (CO_2) is by far the most significant one associated with the operations of most industries and population centers, including universities such as Cornell.

Carbon dioxide is a non-toxic, colorless, odorless gas that is part of many natural processes, including human respiration (in which CO_2 is released) and photo-synthesis in plants (in which CO_2 is absorbed by plants). However, CO_2 can persist in the ocean and atmosphere for centuries. It is also found within the earth and is released in great quantities during the process of fossil fuel combustion, which rapidly liberates the carbon trapped many millennia ago in living things that became the source of the fossil fuels. Because of the GHG effect of CO_2 emissions, its long lifetime in the seas and atmosphere, and its link to fossil fuel combustion, efforts at reducing the human cause of GHG emissions principally revolve around reductions in the combustion of fossil fuels.

To allow for a consistent comparison of GHG sources, CO_2 emissions in this section are reported in units of equivalent pounds (or tons) of CO_2-equivalent (one ton equals two thousand pounds). Since nearly all of Cornell's GHG direct and indirect emissions are CO_2, one pound of CO_2 equivalent is simply an amount of CO_2 emissions weighing one pound. Other data may utilize units of carbon-equivalent, which only counts the weight of the carbon portion of the CO_2 molecule and not the weight of the oxygen portion. The latter method reports a smaller calculated weight for the same amount of emissions.

A. Existing Conditions

As discussed in Section 2.12.1, electrical usage at the Wilson Laboratory, including the Synchrotron, in fiscal years 2007-2010 averaged about 26,000 to 28,000 MWh (Megawatt-hours) per year.

Prior to 2010, about 90 percent of this electricity on average was purchased from New York State Electric and Gas (NYSEG), the local utility. Greenhouse gas (GHG) emissions associated with that energy usage were primarily due to the burning of fossil fuels to generate electricity for NYSEG. The remaining approximately 10 percent of the electricity used was produced from on-campus hydropower or steam turbine co-generation, with year-to-year variations depending on availability.

In 2010, the campus started operation of its Cornell Combined Heat and Power Plant (CCHPP) system which uses natural gas-powered turbines to generate electricity, with the exhaust heat providing steam to campus via heat recovery steam generators (boilers that utilize exhaust heat to make steam). Based on the first year, and over the course of each subsequent year, Cornell's self-generation systems are now expected to provide over 80 percent of the electricity needed for campus, with the remainder being supplied by NYSEG. The GHG emissions associated with usage beyond 2010 is therefore a combination of emissions associated with Cornell's natural gas combustion, hydropower, and steam turbines, together with emissions associated with generation from NYSEG's suppliers.

The Wilson Laboratory office and lab spaces require chilled water for space cooling needs. Chilled water for this purpose has been produced using the heat exchangers of Cornell's Lake Source Cooling system since about 2001. Water from Cayuga Lake provides cooling through heat exchangers located on East Shore Drive. The exchangers transfer heat (but not fluid) between the lake water and the closed-loop campus chilled water system that circulates on campus. The GHG emissions from space cooling are the result of electricity used for the pumps that move lake water to the heat exchangers on the shore and pumps that circulate the closed-loop chilled water between campus buildings and the heat exchangers. These emissions are a fraction of the GHG emissions produced by conventional cooling methods.

The Wilson Laboratory particle accelerator requires a system that utilizes electrically-driven compressors and a radio frequency system to accelerate the particles. The electricity that is required for these systems is a substantial part of the electrical load of the Wilson Laboratory and included in the calculations for electrical requirements in this Section and Section 12.2.1.

The emissions associated with electrical generation, or "emissions factors", vary by service provider. The emission factor values for NYSEG, as with any service provider, change over time as the mix of the fuel sources change. There is a lag in the reporting of these factors. The most recent reporting through the Public Service Commission is for the year ending December 31, 2008. (http://www3.dps.state.ny.us/e/energylabel.nsf/) The published data indicates that NYSEG's emission factor in the latest year of reporting (2008) was about 986 pounds of CO_2 (equivalent) per MWh, reflecting the emissions from a mix of non-GHG sources (hydroelectric, nuclear) and fossil fuel sources which emit GHGs (natural gas, oil, coal). Although the emissions factors change year-to-year, for the purpose of this DEIS, this value of 986 pounds of CO_2 equivalent per MWh will be used to calculate the GHG impact of current and future electricity supplied by NYSEG.

Cornell is a voluntary member of the American College and University Presidents Climate Commitment. See Section 1.10.5. As required by that membership, Cornell calculates GHG emissions associated with both energy generated on campus and energy purchases. These estimates are included in an annual energy and carbon inventory publically available on Cornell's Energy & Sustainability website (http://energyandsustainability.fs.cornell.edu/em/fastfacts/default.cfm).

The emissions generated during energy production by Cornell's utility department are calculated from historical data of the fossil fuel consumption used to generate electricity and steam. Starting in calendar year 2010, Cornell began operating a combustion turbine combined heat and power plant that uses natural gas to create both steam and electricity. A portion of the high-pressure steam is also delivered to steam turbines which produce additional electricity as they convert the high-pressure steam to lower-pressure steam for campus distribution. Therefore, the emissions associated with the natural gas use in the combustion turbines are allocated between both electrical generation and steam production. In calendar year 2010, the utility department determined that Cornell's overall operations resulted in emissions of 1013 pounds of CO_2-equivalent per MWh of electricity produced and 83 pounds of CO_2-equivalent per million British Thermal Units (MMBTU) of steam received at the buildings.

Prior to 2010, Cornell generated a much smaller amount of electricity than it does now, and steam was created by direct combustion of fossil fuels (coal, natural gas, and oil). Because a greater proportion of the small amount that Cornell did generate on campus came from renewable (hydro-electric) or co-generation (steam-turbine) sources, the effective GHG emissions factor from that electricity was lower – about 771 lbs per MWh. Conversely, the effective GHG emissions factor related to the steam production was much higher than since combined heat and power began in January 2010 – about 228 pounds of CO_2-equivalent per MMBTU of steam received at the buildings.

Calculations for current GHG emissions due to the current operations of the Wilson Laboratory are summarized in Table 2.12.g below, based on the energy uses estimated in Section 12.12.1. Cornell reports on a fiscal year (FY) basis running from July 1 to June 30th. Table 2.12.g includes both FY 2009 and FY 2010 emissions to show the differences in electrical production resulting from the introduction of the CCHPP into the Cornell energy mix. The CCHPP went on line halfway through the fiscal year (at the start of calendar year 2010). For the purpose of this table, the emissions factor used for electrical generation on-campus in FY 2010 is 1013 pounds of CO_2 per MWh, the factor associated with the CCHPP, since this accounts for most of the electricity generated in FY 2010. A value of 156 pounds

CO_2-equivalent per MMBTU is used for steam in 2010, representing the average for the transition from pre-CCHPP to post-CCHPP.

Fiscal Year	Cornell Generated Electricity[1] (MWh)	Electricity Purchased[1] (MWh)	Steam Used (MMBtu)[2]	Nat Gas Used (MMBtu)[2]	Total GHG emissions resulting from Existing Wilson Laboratory Operations (Tons CO_2 Equiv.)
2009	2,300	20,800	2,400	1,100	11,483 tons
2010	13,400	13,300	2,300	1,100	13,624 tons
2011(est)[3]	21,600	5,100	2,300	1,100	13,615 tons

Notes: (1) Breakdowns based on proportion of campus electric self-generated each year; figures include electricity needed by Lake Source Cooling for chilled water.
(2) MMBTU stands for millions of British Thermal Units (BTUs), a standard unit of energy.
(3) Estimated based on calendar year 2010 totals, the first full year with CCHPP in service.

Table 2.12.g: Existing Wilson Laboratory Energy Greenhouse Gas Emissions

While campus-wide GHG emissions were reduced sharply in 2010, the GHG emissions for Wilson Laboratory in 2010 (and estimated for 2011) are higher than in 2009. There are two reasons. One is that the Wilson Synchrotron was used for more hours of research in that calendar year, consistent with typical minor year-to-year research time fluctuations which are to be expected. Secondly, the facility uses only a small proportion of steam in proportion to its use of electricity. The benefits of the low GHG-emissions steam that CCHPP provides are not as apparent at Wilson Laboratory compared with other buildings since most of the GHG emissions of CCHPP are derived from the electricity produced.

B. Impacts of the ERL on Greenhouse Gas Emissions

Electrical energy required for the ERL project will come from the same two sources currently used for the existing Wilson Laboratory operations. These sources are Cornell's own generation through the Combined Heat and Power plant (CCHPP), steam turbines, and the hydropower plant, and the local electrical grid via NYSEG. In the first year, starting January 1, 2010, approximately 81 percent of all campus power was produced by Cornell sources. Therefore, for the purpose of this analysis, 81 percent of Wilson Laboratory's existing electrical requirements are attributed to Cornell-generated sources and all additional energy projected for the ERL is calculated as if purchased from the grid. Because the GHG emissions factors associated with NYSEG-delivered power are within about three percent of those calculated for Cornell-produced power, this assumption does not significantly impact the results.

The East and West additions will primarily use exhaust heat from the Cryogenics Plant for building heating needs. The buildings will also use a small amount of cooling for space conditioning, which will be supplied by the Lake Source Cooling system. Lake Source Cooling is more efficient by a factor of eight compared to traditional cooling systems. The electrical requirements associated with both process and space cooling are included in this analysis.

Based on these assumptions, Table 2.12.h documents the anticipated total annual GHG emissions resulting from the Wilson Laboratory energy needs before and after the incorporation of the ERL.

Fiscal Year	Electricity Generated (MWh)	Electricity Purchased (MWh)	Steam Purchased (MMBtu)	Nat Gas Purchased (MMBtu)	Total GHG emissions resulting from Wilson Laboratory Operations (Tons CO_2 Equiv.)
2009	2,300	20,800	2,400	1,100	11,483 tons
2010 (with CCHPP for 6 months)	13,400	13,300	2,300	1,100	13,624 tons
2011 (est)	21,600	5,100	2,300	1,100	13,615 tons
Future with ERL	21,600	119,550	2,500	1,100	70,056 tons

Table 2.12.h: Total Greenhouse Gas Emissions Associated with the Wilson Laboratory Energy Needs, Before and After Incorporation of the ERL

FY 2011 data was estimated by combining the FY 2010 Wilson Laboratory energy use combined with calendar year 2010 Cornell utility operations, the first full year with the CCHPP in operation. These values reflect the best available "before ERL" estimate.

In summary, the project will result in an estimated net annual increase of about 56,441 tons CO_2 equivalent by 2019 when the ERL is built and running. This increase is not inconsequential. Determining its significance requires context and analysis.

The proposed ERL project stands out among other individual facilities because it will consume a large amount of energy. Its GHG emissions are being discussed here for that reason. Such energy usage will be essential to achieving its core mission. While the proposed ERL's mission cannot be achieved in any other way, every effort was made to reduce the need for energy as much as possible. The name of the project, Energy Recovery Linac, tells its story. See subsections 1.1.3 and 1.1.4. The energy recovery feature was invented at Cornell in order to have a brilliant source of x-rays that would use as little energy as possible. It is this feature that has made it feasible to build at all.

The ERL facility was factored in when Cornell made its commitment for achieving carbon neutrality by the year 2050 as part of the American College and University Presidents' Climate Commitment. If the ERL project were not built, this goal, speculatively, might be met slightly earlier but the ERL's benefits would not be realized. The energy consumed by the ERL project will account for about 36 percent of campus electrical power consumption and 30 percent of campus energy-use GHG emissions when it is complete and fully operational in about 2019, assuming other campus-wide energy use remains about constant, i.e., that energy use associated with new buildings and activities are balanced with energy reductions from energy conservation initiatives and activities that end prior to 2019. The existing Wilson Laboratory's GHG emissions were about 13,615 tons CO_2 equivalent or eight percent of the 174,000 tons CO_2 equivalent associated with campus energy use in 2010. GHG emissions associated with commuting, business travel, or other non-utility emissions are not reflected in these totals.

C. Mitigation Measures

Cornell has invested significantly in projects to reduce its GHG emissions footprint over the past decade and has committed, through the President's Climate Commitment, to continue to move towards climate neutrality. While direct purchase of "green" energy is possible, Cornell's Climate Action Plan is aimed at substantially achieving this goal within Cornell's campus, rather than buying offsets or using similar methods to maintain old energy practices here while accounting for reductions elsewhere. Table 12.12.i shows the results of Cornell's GHG emission reductions to date and projections for future years.

Fiscal Year	Annual GHG Emissions (Tons CO_2 Equivalent)	Notes
1990	332,000	Historical Baseline
2008	262,000	
2009	249,000	Significantly reduced coal use in 2009
2010	180,000	CCHPP online for 6 months; coal use ending
2011 (est)	174,000	Calendar Year 2011 total (CCHPP for 12 months)
Current Plus ERL	~231,000	Includes ERL Energy Use based on Current GHG Emission Factors

Table 2.12.i: Greenhouse Gas Emissions Associated with Cornell's Ithaca Campus Utilities (Purchased, Generated Electricity and Chilled Water)

Table 2.12.i provides context to the GHG emissions associated with the operation of the projected energy use of the ERL laboratory. This future estimate does not include other factors that could substantially increase or decrease future GHG-emissions, but is intended only to provide a guide as to the scale of the ERL project's effects on Cornell's overall GHG emissions.

Cornell expects to continue to grow both physically and in the area of research. In the past ten years, Cornell has been successful in maintaining this physical growth without increasing energy use overall through improvements in energy efficiency, better energy standards for new construction and renovations, and innovations at the central heating and cooling facilities. This growth is consistent with the assumptions used in the Climate Action Plan (Section 1.10.5). The Climate Action Plan acknowledges the potential for higher future energy needs due to physical growth and research priorities and provides a framework for reducing the impact of that growth while simultaneously finding replacement energy for the fossil fuels that Cornell now uses to power and heat campus.

Although the energy use of the ERL is high, the estimated annual impact on GHG emissions (increase of approximately 56,500 tons equivalent) is significantly less than the annual GHG emission reduction Cornell will have achieved following the FY 2008-2011 period (reduction of approximately 88,000 tons per year). Because of Wilson Laboratory's disproportionately high use of electricity to heat compared with other campus buildings, as explained above, Wilson's existing operations do not show the significant drop in GHG emissions associated with the campus' overall drop from 249,000 tons CO_2 equivalent to about 174, 000 tons CO_2 equivalent, it is nonetheless relevant that Wilson's existing GHG emissions at 13,615 tons CO_2 equivalent are offset about six times over by the permanent drop in the annual rate of campus-wide GHG emissions between FY2008 and FY2010. The 88,000 tons CO_2 equivalent permanent annual reduction more than offsets the expected annual increase of 56,500 tons CO_2 equivalent due to the proposed ERL project.

Cornell is continuing its commitment to reducing future GHG emissions through energy conservation, innovation, renewable energy demonstration, and similar programs as outlined in the Climate Action Plan (Section 1.10). Campus-wide initiatives will help mitigate the proposed project's GHG emissions. Strategies include methods to offset the electricity generated through the combustion of fossil fuels with energy produced by non-fossil energy sources and/or through more efficient fossil sources. As described in the Climate Action Plan, Cornell continues to actively pursue multiple opportunities for replacing fossil-based power sources.

In addition to the energy recovery principle of the ERL, the proposed project recycles waste heat from the Cryogenics Plant. This offsets the fossil fuel used at the CCHPP for the production of steam currently used for these purposes, thus reducing GHG emissions further on a campus-wide basis.

With its mitigation measures, the proposed ERL project's GHG emissions will be as low as practicable in light of the needed energy to achieve its scientific mission. This mission will have far-reaching, positive social impacts that environmental review considers in addition to environmental impacts. Additionally, the ERL is unlikely to be duplicated elsewhere in the United States. The potential adverse environmental impact from GHG emissions can be thought of as dispersed over a far wider area than the community, state, or region since scientists and students from a far wider area will use the proposed ERL and society as a whole will be the beneficiary. In such a context, the expected increase in GHG emissions is relatively moderate and offset by the benefit to society.

D. Significant Unavoidable Adverse Impacts

This project will require a large amount of electricity that will contribute to greenhouse gas emissions. A net increase of approximately 56,500 tons CO_2 equivalent annually is forecast when the ERL is fully operational. The project cannot achieve its research objectives without this supply of electricity. This is a moderate unavoidable adverse impact of the proposed project that is offset by the project's benefit to society.