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Greenhouse Gas Emissions Inventory
of the Centralized Renewable Energy System (CRES)
at Nebraska Innovation Campus

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ABSTRACT

The Centralized Renewable Energy System (CRES) at Nebraska Innovation Campus (NIC) is a heat-exchanger system that utilizes reclaimed, non-drinkable water from the nearby water treatment plant to heat and cool a projected 1.675 million square feet of office and lab space. A greenhouse gas emissions inventory was estimated for the CRES operating at full build-out of the campus in 2035, compared to conventional office space, being a control system with standard chiller and boiler configuration. The control system is estimated to emit 30,787 metric tons of carbon dioxide-equivalent per year (Mg CO_2e yr-1), whereas heating and cooling Nebraska Innovation Campus supplemented by CRES is estimated to emit only 15,637 Mg CO_2e yr-1 from electricity use for chillers and pumps, roughly 49% less greenhouse gas emissions compared to the control system, at a savings of roughly 9 kilograms of CO_2e per year per square foot.
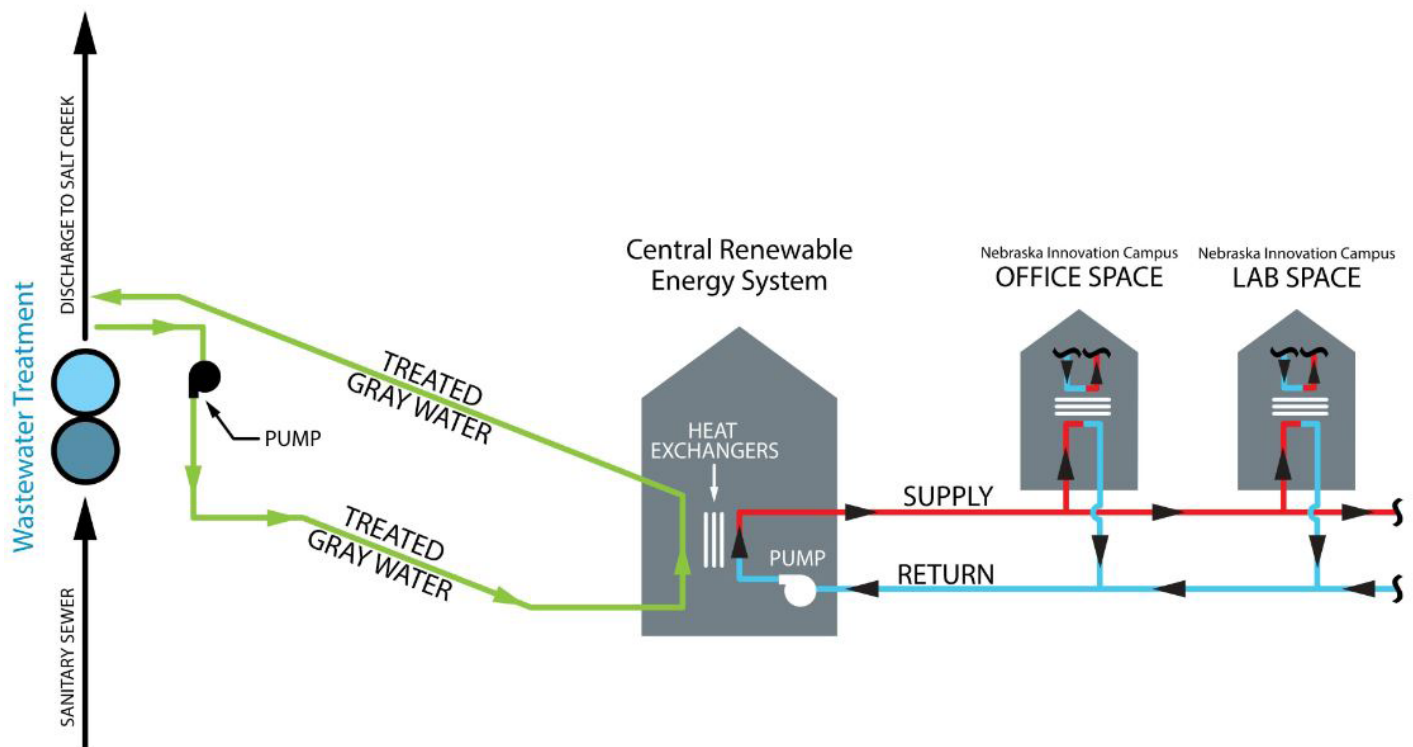
INTRODUCTION

Nebraska Innovation Campus (NIC) is a research campus designed to facilitate new and in-depth partnerships between the University of Nebraska-Lincoln (UNL) and private sector businesses. By connecting the talents of experts, companies, and the university, NIC creates a unique culture of innovation. NIC is adjacent to UNL and strategically provides access to research faculty, facilities, and students.

The campus employs the newest and most creative technologies for heating and cooling. The Centralized Renewable Energy System (CRES) uses reclaimed, non-drinkable water from the nearby water treatment plant to heat and cool the 1.675 million square feet of offices and labs at NIC. The award winning closed-loop system transfers thermal energy in underground piping to the entire NIC campus. This system is more efficient than a geothermal system because of the consistent water temperatures provided by Lincoln's wastewater treatment facility. Today, there are less than a dozen similar projects in the U.S., where CRES will be one of the largest and most unique among the similar facilities.

Water temperatures from the water treatment plant range from roughly 57 to 75°F and are expected to have flow rates of 16.5 million gallons per day (MGD) in the winter and 10.4 MGD in the summer. At these temperatures, buildings will be able to utilize heat-exchanger and pump configurations that can operate with a 25% energy savings in the summer cooling months (Olsson Associates 2013); in the summer, the heat sink is the water treatment effluent as opposed to air cooling or cooling tower, but electricity is still used to transfer heat via building chillers. In summer, water will inflow at 75°F and heat from inside of the building will be transferred to water outflow at roughly 85°F (outflow temperatures must remain below 90°F per Nebraska Department of Environmental Quality requirements); this heat transfer occurs via a standard heat rejection loop for chillers.

In Winter water inflow at 57°F will transfer heat to inside air and thereby reduce outflow temperatures to roughly 47°F, offsetting any need for natural gas for heat, on average. Compared to conventional boiler and chillers with a 30-year lifespan, the CRES is projected to have a 50-year lifespan.

This study estimates the greenhouse gas (GHG) emission savings of the CRES system relative to a control system, which is office space with conventional heating and cooling infrastructure. In addition to saving energy and GHG emissions, numerous studies of related practices to increase industrial efficiency have been widely shown to increase the profitability and competitiveness of many businesses (e.g. Walmart, GE, 3M, DuPont, BP) (Esty & Winston 2006; Winston 2009). In these cases, life cycle assessment (LCA) is a key tool to identify environmental impacts of interest for regulators and investors and provide information to better manage large production systems for improved efficiency (Esty & Winston 2006).

CRES Diagram
Source: Nebraska Innovation Campus

METHODOLOGY

Performance data on the CRES were obtained from Olsson Associates (Lincoln, NE), which included modifications from HDR (Omaha, NE) (excel spreadsheet, May 5, 2013). Olsson Associates estimated projected annual heating and cooling demand for CRES after a 20-year build-out period for 1.675 million square feet for office, laboratory, event, and classroom space at NIC. In 2035, the CRES coupled with building chillers will supply the entire HVAC demand for NIC, and no supplemental natural gas for heat was estimated to be used. The CRES requires nearly continuous electricity demand for two sets of pumps: one for circulating water from the water treatment facility to discharge in Salt creek, and a second set of pumps for circulating water within NIC. Electricity use for pumps and building chillers cause indirect GHG emissions from electricity generation (Graedel & Allenby 2010, Liska et al. 2009, Liska & Perrin 2010).

LCA quantifies energy and material flows in industrial systems and estimates corresponding environmental impacts and provides information for increasing system efficiency (Graedel & Allenby 2010, Liska et al. 2009, Liska & Perrin 2010). A general principle of LCA is to use the same system boundaries for comparing alternative similar systems. In the control system, GHG emissions were estimated for natural gas used for heating and electricity used for cooling. Emission factors for natural gas use were obtained from Lincoln/Lancaster Department of Health, and emissions from cooling were estimated using 2010 emission factors for electricity from the U.S. Environmental Protection Agency (EPA 2010). For comparison, emissions from heating and cooling a conventional office were estimated based on the same heating and cooling demand as NIC in 2035.

RESULTS

By 2035, the CRES is estimated to service 1.675 million square feet of office and lab space on NIC. At that time, electricity for the CRES pumps is estimated to annually use 1,179,212 kilowatt-hours (kWh), with corresponding indirect GHG emissions of 826 metric tons (Mg) of carbon dioxide-equivalent (CO2e) from electricity generation (Table 1). In the summer months, the CRES-NIC system is estimated to require roughly 96,158 million btu, corresponding to an emission of 14,811 Mg CO2e. For a comparable office space in Lancaster County, natural gas use for heating and electricity for cooling is estimated to emit 30,786 Mg CO2e, which corresponds with 97% greater GHG emissions than the CRES-NIC system. On a square foot basis, the CRES is estimated to save 9.0 kilograms (kg) of CO2e per year compared to conventional infrastructure for heating and cooling.
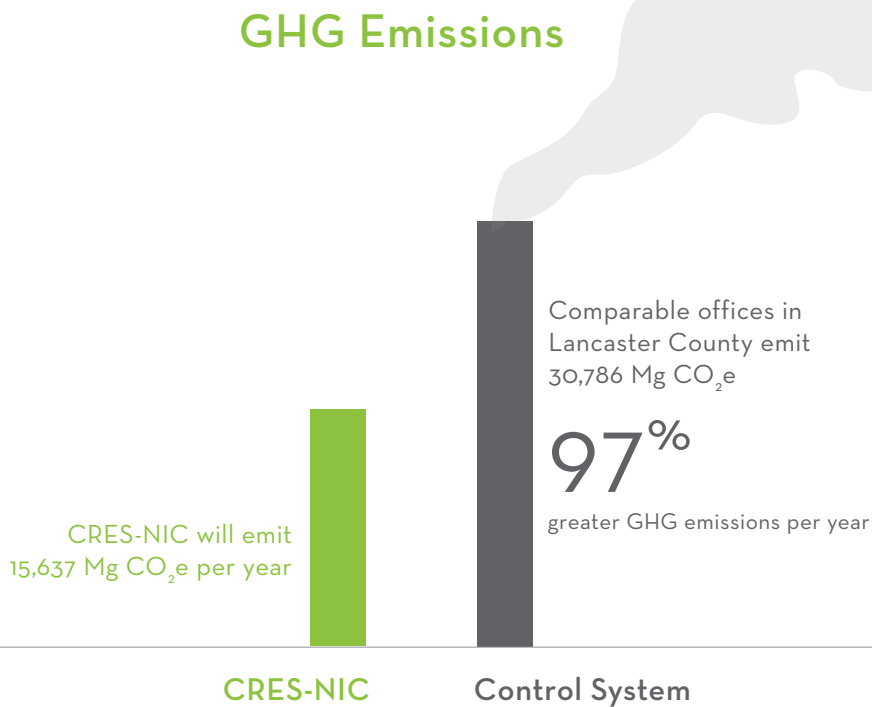
GHG Emissions

Comparable offices in Lancaster County emit 30,786 Mg CO_2e

$97^{\%}$

greater GHG emissions per year

CRES-NIC will emit 15,637 Mg CO_2e per year

CRES-NIC   Control System

Table 1. Greenhous gas emissions from the CRES-NIC system compared to conventional office space in 2035.

20 Year Build Out, NE CRES System		Greenhous gas, Mg CO_2e [1]
Area[2], million square feet (sf)	1.675	–
Heating Demand[3], btu yr^{-1}	207,036,000,000	–
Natural gas[4] btu yr^{-1}	–	–
Cooling Demand[5], btu yr^{-1}	96,157,519,920	
Cooling NE electricity[6,7] kWh y^{-1}	21,135,741	14,811
Pump electricity[8,7] kWh yr^{-1}	1,179,212	826
20 Year Build Out, NE Control System		
Area[2], million sf	1.675	–
Heating Demand[3], btu^{-1}	207,036,000,000	–
Natural gas[9], million cubic feet yr^{-1}	201.593	11,038
Cooling Demand[5], btu y^{r-1}	96,157,519,920	–
Cooling NE electricity[6,7] kWh yr^{-1}	28,180,988	19,748
Cumulative GHG Emissions		
CRES 2035, emissions yr^{-1}		15,637
Control 2035, emissions yr^{-1}		30,786
Total Mg Co_2e savings (Control - CRES) yr^{-1}		15,149
kg CO_2e GHG savings (Control - CRES) sf^{-1} yr^{-1}		9.0

[1] Carbon dioxide-equivalent (CO_2e) = CO_2 + CH_4 (methane) +N_2O (nitrous oxide). The global warming potential for methane is estimated to be 25 times greater than CO_2, and the global warming potential for nitrous oxide is 298 times greater than CO_2 (EPA 2014).

[2] Year 20 build-out gross area includes the buildings: 4H, IAB, Life Science, 19 x 75,000 sf. Square footage provided by Stefan Newbold, Engineering Manager, UNL Facilities Planning and Construction (April 24, 2015).

[3] Estimated Diurnal Curve Simulation, OA/HDR (May 1, 2013) "HX Plant Year 20"[G331]

[4] Natural gas usage provided by Stefan Newbold, (April 24, 2015).

[5] Estimated Diurnal Curve Simulation, OA/HDR (May 1, 2013) "HX Plant Year 20"[G332]. One refrigeration ton is 12,000 btu per hour (ASHREA 2015).

[6] The CRES system (water-to-water heat pump) is 25% more energy efficient in the summer compared to an air-cooled chiller, based on ASHREA maximum allowable efficiencies (calculated by Olsson Associates). Data from the Estimated Diurnal Curve Simulation, OA/HDR (May 1, 2013). [7] Emission factors from electricity eGRID 9th edition Version 1.0 Sub-region File (Year 2010 data) MROW sub-region: eGRID subregion MROW, annual CO_2 total output emission rate of 1,536.3605 lb/MWh, annual CH_4 total output emission rate of 0.0285278 lb/MWh, annual N_2O total output emission rate 0.0262911 lb/MWh (EPA 2010).

[8] Pump electricity demand provided by Dave Roberts, Mechanical Electrical Team Leader at Olsson Associates.

[9] 1,027 btu per cubic foot of natural gas. Combustion of 1 million cubic feet of natural gas (MMcf) in an institutional boiler creates the following emissions: 120,000 pounds of carbon dioxide (CO_2), 2.3 pounds of methane (CH_4), 2.2 pounds of nitrous oxide (N_2O); Emissions were estimated based on local emissions factors for natural gas heating during 2015 (Gary R. Bergstrom Jr., Senior Environmental Health Specialist, Lincoln/Lancaster County Health Department, April 23, 2015).

Uncertainties in Estimation of GHG Emissions Savings

NIC currently purchases electricity from Lincoln Electric System. In the future, local electricity generation systems are expected to use more wind, natural gas, and solar, instead of coal, which will lower GHG emissions (Lincoln Electric System 2014). Due to a decrease in this emissions intensity, the difference in GHG emissions between the CRES-NIC system and conventional infrastructure will decrease with implementation of lower-emission electricity sources (e.g. renewables). Thus by 2035, the estimated GHG emissions savings of the CRES-NIC system could be lower than estimated here due to this factor.

Emissions of GHGs from the Salt Creek could be slightly reduced from the CRES-NIC system. In general, these emissions probably increase with water temperature. Heated water from the treatment plant would probably increase GHG emissions relative to a stream without this effluent. In winter, CRES-NIC is a net heat sink and reduces effluent temperature, and thus GHG emissions from the stream. In summer, CRES-NIC is a net heat source, which probably increases GHG emissions, but increases in summer would be offset by decreases in winter. Over the past 20 years, Lincoln has had more heating degree days than cooling degree days (Nebraska Energy Office 2015). More heating degree days (i.e. increased energy demand to heat buildings, rather than cool them) suggests that the CRES-NIC would be a net heat sink on average, which should correspond to some unknown marginal decrease in GHG emissions from the stream. Estimation of changes in stream GHG emissions would require measurements of current stream characteristics, which was beyond the scope of this study. The rate and quality of the effluent from the treatment plant will also probably change over time, as well as the ratio of heating-to-cooling degree days in Lincoln, both of which add further uncertainty to these estimations.

In many life cycle assessments, the energy use and GHG emissions for producing and constructing the infrastructure would also be estimated (Liska et al. 2009, Liska & Perrin 2010, Graedel & Allenby 2010). In the above analysis, only operational GHG emissions from the system were estimated. If infrastructure emissions were estimated to produce the materials used in CRES-NIC and included in the GHG inventory, the difference in emissions between the conventional system and the CRES-NIC would be reduced due to this factor.

Acknowledgments

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