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Assessment of Impacts from Adopting the 2006 International Energy Conservation Code for Residential Buildings in Illinois

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Summary

The state of Illinois currently does not have a statewide building energy efficiency code for residential buildings, although a number of jurisdictions in Illinois have adopted the 2000 or 2003 Editions of the International Code Council's (ICC) *International Energy Conservation Code* (IECC) (ICC 1999, 2003). DOE has requested Pacific Northwest National Laboratory (PNNL) to estimate the energy savings, economic impacts, and pollution reduction from adopting the 2006 IECC. This report addresses the impacts for low-rise residential buildings only.

The analysis indicates that homes built to meet the IECC requirements will save Illinois homeowners money by reducing long-term energy costs by far more than the construction-related cost increases. Homeowners with a typical mortgage should realize a net positive cash flow within a few years or less in most cases. Benefit/cost ratios range from 1.5 to 3.9. The analysis also indicates that a significant improvement in pollution reduction can be achieved over time as more and more buildings are built to the code. Construction cost increases and energy savings will vary depending on many factors, including location, fuel prices, house size and characteristics, material and labor costs, and the energy efficiency measures used to comply with the 2006 IECC.

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1.0 Introduction

The state of Illinois currently does not have a statewide building energy efficiency code, although a number of jurisdictions have adopted the 2000 or 2003 Editions of the International Code Councils' (ICC) *International Energy Conservation Code* (IECC) (ICC 1999, 2003). This report provides estimates of the energy savings, economic impacts, and pollution reduction from adopting the latest version of the IECC, the 2006 IECC (ICC 2006), for low-rise residential buildings.

Section 2 of this report contains an overview of the 2006 IECC. Assumptions used in the analysis are discussed in Section 3. Section 4 discusses the impacts from adopting the 2006 IECC for residential buildings in Illinois. Section 5 provides conclusions from the analysis and Section 6 contains a list of publications referenced in this report.

2.0 Overview of the 2006 IECC

The IECC is a nationally recognized model code that contains requirements for the energy efficient design and construction of all building types, in all U.S. locations. Chapter 4 of the IECC contains specific requirements for residential buildings and Chapters 1 and 2 contain general information applicable to both residential and commercial buildings. The residential building category includes single-family houses, duplexes, and multifamily residential buildings three stories or less above-grade in height. Multifamily buildings include apartments, condominiums, and dormitories, but do not include hotels and motels. Commercial buildings are addressed in Chapter 5 and referenced standards are listed in Chapter 6.

For residential buildings, the IECC addresses energy use from space heating, space cooling, and water heating. Energy savings resulting from the IECC will be from reduced space heating and air conditioning; current construction practice is assumed to comply with the IECC for water heating.

Perhaps the most significant requirements for residential buildings are the insulation levels for the building envelope. The envelope includes walls, windows and skylights, doors, ceilings, floors, and the perimeter of slab-on-grade foundations. These envelope requirements become more stringent as the climate becomes colder, so more insulation and better windows are required in northern Illinois compared to southern Illinois. All openings, such as penetrations and cracks in the building envelope, must be sealed.

The IECC contains limited requirements for space heating and cooling systems and domestic water heating systems (for showers, sinks, clothes washing, etc.). Efficiency requirements for mechanical equipment types (furnaces, boilers, heat pumps, etc.), that are part of these systems, are set by Federal law and cannot be altered by codes such the IECC. The IECC sets requirements for mechanical system controls, duct sealing and insulation, piping insulation, circulating hot water systems, mechanical ventilation and equipment sizing.

The IECC has important requirements for sealing and insulating ductwork that passes through unconditioned spaces, such as unheated basements and attics. The benefits from duct sealing will not be realized unless they are complied with by builders and subcontractors and enforced by code officials. One study has shown that enforcement can be a problem (Washington State University 2001). Where sealing requirements are properly implemented, numerous studies have shown that the energy loss from ducts passing through unconditioned spaces and the potential savings is very significant (Boe 1998; Coito et al. 1998, Hammon and Modera 1996).

The IECC contains three alternative compliance paths: simplified prescriptive requirements, a total building envelope UA (U-factor multiplied by area) approach, and a simulated performance approach. The IECC allows trade-offs where some energy efficiency measures can fall below code requirements for a specific measure if other measures exceed code requirements. For example, it often is possible to reduce wall insulation and/or other insulation levels if a high-efficiency furnace is used. The

IECC allows trade-offs as long as the estimated total annual energy cost does not increase.[1] Several relatively easy-to-use software products are available to assist in designing a building that complies with the IECC, including DOE's free RES*check*™ software (DOE 1995).

The 2006 IECC has a prescriptive compliance path that is much simpler to use than those in previous versions of the IECC. The 2006 IECC has a single table of requirements for insulation R-values and window U-factors that apply to all low-rise residential buildings (the same requirements apply to single-family and multifamily). In contrast, earlier versions of the IECC contain nine tables of R-value/U-factor requirements, and the user had to calculate the window-to-wall area ratio to determine the appropriate table.

The 2006 IECC has a simple and clear map-based format for presenting code requirements that vary by climate, where the appropriate climate zone can easily be determined from a county map of the U.S. The 2006 IECC has eight primary climate zones, from hot locations (i.e., southern Florida) to very cold locations (i.e., northern Alaska). Illinois falls into two zones (Zones 4 and 5). County borders set climate zone boundaries. To eliminate any doubt about which climate zone applies to a location, a table of climate zones by county is provided in the code. Figure 1 shows the climate zones in Illinois and the simplified prescriptive envelope requirements for the 2006 IECC.

[1] Local jurisdictions may, at their discretion, require that site energy use (Btu) be balanced rather than energy cost.

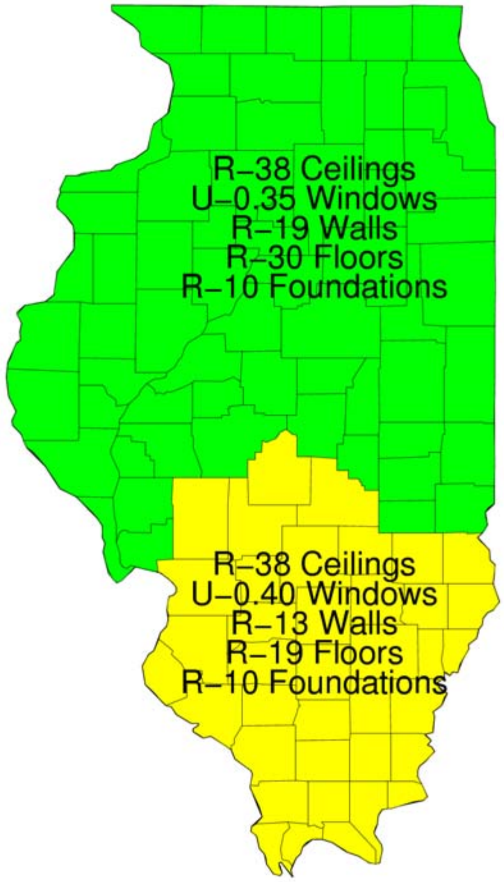

Figure 1. Prescriptive Envelope Requirements in the 2006 IECC

3.0 Assumptions Used in the Analysis

Some of the IECC requirements are already standard practice in new housing in Illinois. For example, thermostats must be installed. Other requirements in the IECC often go beyond what is typically installed in new housing. To determine how the IECC will alter residential building construction Illinois, an assumption of "current practice" was first developed. The survey data used was collected by the Midwest Energy Efficiency Alliance (MEEA 2003) and the National Association of Home Builders (NAHB) Research Center.

Table 3.1 shows assumed insulation levels and whether low-E glazing was used in windows in the analysis for current practice and for IECC compliance for Chicago and East St. Louis (representative cities for climate zones 5 and 4, respectively).

Table 3.1. Energy Efficiency Measures Assumed for Current Practice and IECC Compliance

	Chicago		**East St. Louis**	
	Current Practice	**IECC**	**Current Practice**	**IECC**
Ceiling	R-30	R-38	R-30	R-30
Wall	R-13	R-19	R-13	R-13
Window U-factor	U-0.48 (no low-E)	U-0.35 (low-E)	U-0.48 (no low-E)	U-0.40 (low-E)
Floors Above Unheated Basements	R-13	R-30	R-13	R-19
Basement Walls (heated basements)	R-13	R-13	R-13	R-13
Duct Insulation	None	R-8	None	R-8
Heating System	Gas furnace, 78% AFUE	Gas furnace, 78% AFUE[(a)]	Gas furnace, 78% AFUE	Gas furnace, 78% AFUE
Cooling System	Air conditioner, 13 SEER	Air conditioner, 13 SEER	Air conditioner, 13 SEER	Air conditioner, 13 SEER
(a) The option of a 90% efficient furnace allowing R-13 wall and floor insulation is also examined for IECC compliance in Chicago.				

The analysis assumes a two-story, single-family house with a conditioned floor area of 2,400 ft^2 excluding the basement. It was assumed that the house had 8.5-ft-high ceilings, a ceiling area (bordering the unconditioned attic) of 1,200 ft^2, a gross exterior above-grade wall area of 2,380 ft^2, a basement ceiling area of 1,200 ft^2, and a basement wall area of 1,120 ft^2. It was assumed that the house had a total opaque (non-glass) door area of 42 ft^2 (two doors) and a window area of 357 ft^2 (15% of the above-grade wall area). Both heated and unheated basements were analyzed. A heated basement is assumed to be fully conditioned space maintained at the same temperature as the rest of the house.

4.0 Impacts from Adopting the 2006 IECC in Illinois

The assessment of the impacts from adopting the 2006 IECC for residential low-rise buildings in Illinois includes construction costs impacts, energy savings, mortgage-related cost impacts to consumers, life-cycle cost impacts, and aggregate statewide impacts.

4.1 Construction Cost Impacts

The analysis used to determine the cost effectiveness of adopting the 2006 IECC in Illinois requires information on cost increases in insulation, window measures, and improved furnace efficiency. Estimating construction costs is the most difficult and uncertain step in assessing the cost effectiveness of energy codes. Costs can vary greatly depending on the builder, subcontractors, and materials and equipment suppliers. Costs may decrease after the market adapts to the code requirements and the energy-efficient products required by the code become prevalent. The costs reported here include the builder's profit and represent the sales value of the house.

Above-grade wall insulation increases from R-13 to R-19 were obtained from R.S. Means (2004) and are $0.38/ft^2$ for the increased framing thickness and $0.10/ft^2$ for the thicker insulation. The 2006 IECC requires R-30 floor insulation in most of Illinois, whereas the current practice is assumed to be R-13. R.S. Means reports an incremental installed cost of $0.33/ft^2$ for R-30 floor insulation compared to R-19 and $0.16/ft^2$ for R-19 compared to R-13. For ceiling insulation, R.S. Means reports $0.18/ft^2$ for the improvement from R-30 to R-38. These costs were used in the analysis.

The improvements to windows needed to achieve U-factors low enough to comply with the IECC are expected to be primarily from the addition of low-E coatings on double-pane windows. A Building America team member estimates typical cost increases of $300 per house for windows meeting Energy Star (U-0.35 in cold climates) ratings (Edminster et al. 2000). The Northwest Energy Star Window Project reports an incremental retail cost of $0.89/ft^2$ from seven manufacturers to improve windows from U-0.44 to U-0.34 (Quantec 2002). A recent report from California suggests a $0.15/ft^2$ incremental cost for manufacturing low-E windows (PGE 2006). A conservatively high cost of $1/ft^2$ was assumed for the addition of low-E coatings to a vinyl or wood double-pane window. Approximately 60% of new residential windows nationwide are low-E, indicating the cost of this feature is apparently low enough that it is close to becoming standard practice (Door and Window Maker Magazine, April 2005).

Duct insulation costs were obtained from R.S. Means (2004). The installed cost for 1½ in. of duct wrap insulation is $2.19/ft^2$. This insulation has an out-of-package R-value of about 5. It was assumed that 216 ft^2 of supply duct surface area and 100 ft^2 of return duct surface in the basement would require insulation for the unheated basement scenario. The total cost for insulating the ducts to R-5 is $692. The 2006 IECC requires R-8 on both supply ducts and return ducts in unconditioned spaces. Because most of the cost for duct insulation is from the cost of labor to install the insulation (R.S. Means reports only an extra 2 cents/ft^2 material cost for 1-1/2 in. insulation compared to 1 in. insulation), the incremental cost of R-8 instead of R-5 for supply ducts should be relatively small. Therefore, a cost of

$800 was assumed to insulate ducts. A study commissioned for the California energy code found that the estimated cost for improved duct sealing is between $100 and $150 (California Energy Commission 2000). A cost of $150 for the duct sealing necessary to meet code was assumed here for the unheated basement design (equivalent duct sealing for the code and current practice in the heated basement design as all ducts are inside the conditioned space).

One method of obtaining credit towards IECC compliance is the use of high efficiency natural gas furnaces. This allows reductions in other energy efficiency levels—for example, to R-13 floor insulation and 2-by-4 walls with R-13 insulation instead of 2x6 walls with R-19 insulation in climate zone 5 in this analysis. This option was examined as an alternative method of complying with the IECC because of the cost effectiveness and popularity of this trade-off. A 90% (or higher) annual fuel utilization efficiency (AFUE) condensing furnace is a substantial improvement in efficiency over a "standard" furnace with an efficiency of about 80%. Condensing furnaces have gained significant market share in recent years, increasing from 28% in 2002 to 34% nationwide in 2005 (http://www.gamanet.org/gama/stats.nsf). A Wisconsin survey reported that 85% of furnace sales in 1996 in Wisconsin were at the 90%+ efficiency level (Energy Center of Wisconsin 1997). This same study indicated that the average cost of improving from a standard efficiency furnace to the 90% efficiency condensing furnace was $464. California data gives an incremental equipment cost of $659 for an 80 kBtu/hr 90% AFUE gas furnace (Itron 2005). A Midwest builder reported the cost at $500 (Energy Design Update 1998). An incremental cost of $600 was assumed for this analysis.

Table 4.1 summarizes these construction costs for energy efficiency measures required by the 2006 IECC. Heated and unheated basements are examined separately. The option of a high efficiency furnace with reduced insulation is examined for Chicago only. Note again that other combinations of improvements in energy efficiency measures can be used to comply with the 2006 IECC and might have a different cost. Actual construction costs related to IECC compliance may vary from those in this report depending on differences in design and construction. As the energy efficiency measures required by the code gain a larger market share and builders find low-cost methods of meeting the code, it is expect that the first cost impacts of the code will drop.

Table 4.1. Construction Costs (Incremental Relative to Current Practice) for IECC Energy Efficiency Measures

	Chicago – Prescriptive Option		Chicago – High Efficiency Furnace		East St. Louis	
	Unheated Basement	**Heated Basement**	**Unheated Basement**	**Heated Basement**	**Unheated Basement**	**Heated Basement**
Ceiling	$216	$216	$216	$216	$216	$216
Wall	$951	$951	0	0	0	0
Window U-factor	$357	$357	$357	$357	$357	$357
Floors Above Unheated Basements	$588	0	0	0	$192	0
90% Efficient Gas Furnace	0	0	$600	$600	0	0
Duct Insulation	$800	0	$800	0	$800	0
Duct Sealing	$150	0	$150	0	$150	0
TOTAL	$3062	$1524	$2123	$1173	$1715	$573

4.2 Energy Savings

The EnergyGauge simulation tool (Florida Solar Energy Center) was used to estimate the energy savings from the building envelope improvements necessary to meet the IECC for the prototype house. The latest available costs for natural gas and electricity were obtained from the DOE Energy Information Administration. Natural gas prices have increased dramatically in the past 5 years, and peaked above $13 per thousand cubic feet (approximately equal to a million Btus) in Illinois for the residential market last winter (DOE/EIA http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_SIL_m.htm). Recent (July 2006) DOE fuel price Short Term Energy Outlook projections (DOE/EIA 2006) estimate residential natural gas prices in the East North Central region to be around $12 to $13 per thousand cubic feet for the next few years during the winter. A natural gas cost of $12/MBtu was assumed in this analysis. The electricity price for air conditioning was assumed to be 8.9 cents/kWh based on Illinois average summer 2005 prices in Illinois (DOE/EIA http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html) (summer of 2006 prices are not available from EIA at the time the analysis was conducted) .

One study estimates heating and cooling savings from improved duct sealing to be 12% in new homes (Hammon and Modera 1996). Another report predicts that sealing 80% of the duct leaks in the basement and insulating the basement ducts to R-5 will produce a 10% savings in energy use (Triedler 1993). Duct sealing measures in existing homes achieved a 5% to 10% annual energy use reduction (Boe 1998). The potential for properly sealing ducts is better in a new building than in a retrofit because the ducts will be fully accessible. For this analysis, we assumed that HVAC energy costs will decrease 10% by sealing and insulating the ducts as required by the IECC. The benefits from code requirements for duct sealing (or the construction cost increases) will not be realized unless they are complied with by builders and subcontractors and enforced by code officials. (Washington State University 2001).

Tables 4.2 and 4.3 show the annual energy use that will result from complying with the IECC requirements and current practice, and the savings over current practice. Table 4.2 is for the unheated basement scenario and Table 4.3 is for the heated basement scenario.

Table 4.2. Annual Energy Cost and Savings from Compliance with IECC – Unheated Basement - Prescriptive Measures

	Chicago			East St. Louis		
	Heating	**Cooling**	**Total**	**Heating**	**Cooling**	**Total**
IECC	$883	$99	$982	$739	$210	$949
Current Practice	$1301	$127	$1428	$963	$278	$1241
Total Savings	$418	$28	$446	$224	$68	$292
Percent Savings	32%	22%	31%	23%	24%	24%

Table 4.3. Annual Energy Cost and Savings from Compliance with IECC – Heated Basement - Prescriptive Measures

	Chicago			East St. Louis		
	Heating	**Cooling**	**Total**	**Heating**	**Cooling**	**Total**
IECC	$1273	$96	$1369	$1027	$223	$1250
Current Practice	$1406	$124	$1530	$1040	$259	$1299
Total Savings	$133	$28	$161	$13	$36	$49
Percent Savings	9%	23%	11%	1%	14%	4%

As described in Sections 3 and 4, the option of complying with the IECC with a 90% efficient natural gas furnace was also examined. This allows a reduction to R-13 wall insulation and R-13 floor insulation, which are the same as assumed current practice insulation levels in Illinois. The energy impacts of this IECC compliance option are shown in Table 4.4.

Table 4.4. Annual Energy Cost and Savings from Compliance with IECC – High Efficiency Furnace Trade-Off

	Chicago					
	Unheated Basement			Heated Basement		
	Heating	Cooling	Total	Heating	Cooling	Total
IECC	$860	$96	$956	$1193	$103	$1296
Current Practice	$1301	$127	$1428	$1406	$124	$1530
Total Savings	$441	$31	$472	$213	$21	$234
Percent Savings	34%	24%	33%	15%	17%	15%

4.3 Economic Impacts Accounting for Mortgages

Because most houses are financed, consumers will be very interested in the financial impacts of buying a home that complies with the 2006 IECC requirements. Mortgages spread the payment for the cost of a house over a long period of time. In this analysis, a fixed-rate mortgage was assumed. It was also assumed that homebuyers will deduct the interest portion of the payments from their income taxes.

The financial and economic parameters required for input to this analysis are summarized below. These parameters are used to calculate the costs and benefits of increased energy efficiency from the homeowner's perspective. A relatively low down payment and a moderate federal income tax rate were selected.

New-home mortgage parameters:

- 7.0% mortgage interest rate (fixed rate)
- points and loan fees equal to 1.6% of the mortgage amount
- 30-year loan term
- 10% down payment.

Other rates and economic parameters:

- 7% nominal discount rate
- 28% marginal federal income tax, 3% state income tax
- 1.5% property tax
- 3% nominal inflation for fuel prices
- 30-year analysis period, no residual/salvage value

Table 4.5 shows the impacts to consumers' cash flow resulting from IECC compliance. The up-front costs include the down payment, points, and loan fees. The savings from income tax deductions for the mortgage interest will slowly decrease over time. The annual values shown in the table are for the first year. Table 4.5 also includes increases in annual property taxes because of the higher assessed house values. The net annual cash flow includes energy costs, mortgage payments, mortgage tax deductions, and property taxes but not the up-front costs.

Table 4.5. Impacts to Consumers' Cash Flow from Compliance with IECC

	Chicago				East St. Louis	
	IECC Prescriptive Option		High Efficiency Furnace Option		IECC Prescriptive Option	
	Unheated Basement	Heated Basement	Unheated Basement	Heated Basement	Unheated Basement	Heated Basement
Up-Front Costs	$343	$171	$238	$132	$192	$64
Annual Energy Savings	$446	$161	$472	$234	$292	$49
Annual Mortgage Increase	$230	$114	$159	$88	$129	$43
Annual Income Tax Deduction Increase	$63	$31	$43	$24	$35	$12
Annual Property Tax Increase	$43	$22	$30	$16	$25	$8
Net Annual Cash Flow Savings (excluding up-front costs)	$232	$57	$340	$161	$182	$10
Benefit/Cost Ratio	2.6	1.8	3.9	3.5	3.0	1.5
Net Present Value Savings	$4534	$1190	$6004	$2846	$3266	$242
Time to Net Positive Cash Flow	1.5 years	3 years	0.8 years	0.9 years	1.1 years	6 years

4.4 Aggregate Statewide Impacts

All results discussed in previous sections have been at the individual house-by-house level. In Table 4.6, the results are aggregated to a statewide total, assuming a code would be adopted statewide in 2007. The results for the prototype houses in Chicago and East St. Louis were combined to obtain an estimated state average (because over 95 percent of Illinois' estimated population growth between 2000 and 2005 was in zone 5, results for Chicago were conservatively assumed to have 90% of the weight in determining the state average). The Department of Census data on building permits reports that about 67,000 residential units were built in 2005 (U.S. Census Bureau 2006). In Table 4.5, the "Annual" results are the first year savings for the 67,000 units that are assumed will be built each year. The cumulative savings in 2010 (assumes the code will be in place for 3 years) and 2020 (13 years) account for the fact that each year, more and more buildings will be built under the code and that annual savings for individual buildings will accumulate over multiple years. Pollutant emission rates were obtained using the EnergyGauge software.

It is important to stress that the energy savings from the code requirements will only be achieved through full and thorough enforcement of the code. For example, if duct sealing practices are not improved, the estimated annual savings decrease by one-third to $15.8 million a year at the statewide level.

Table 4.6. Aggregate Statewide Impacts from Compliance with IECC

	Annual	**Cumulative**	
		2010	**2020**
Energy Cost Savings	$24.0 Million	$144 Million	$2.2 Billion
Electricity Savings	37 Million kWh	220 Million kWh	3380 Million kWh
Natural Gas Savings	1720 GBtu	10340 GBtu	157 TBtu
SO_2 Reduction (tons)	304 tons	1823 tons	27,600 tons
NO_x Reduction (tons)	190 tons	1141 tons	17,300 tons
CO_2 Reduction (tons)	141,000 tons	847 thousand tons	12.8 million tons

5.0 Conclusion

If the IECC were adopted by jurisdictions in the state of Illinois, or statewide, substantial improvement is expected in the energy efficiency of residential buildings. While the initial cost of construction will rise, energy bills will be substantially reduced. Construction cost increases and energy savings will vary depending on many factors, including location, fuel prices, house size and characteristics, material and labor costs, and the energy efficiency measures used to comply with the 2006 IECC. The analysis indicates that construction costs for the energy efficiency measures evaluated in the study would cost approximately $2,100 and 1,200 in climate zone 5 (the northern two-thirds of Illinois) for a house with an unheated basement and a heated basement, respectively. Costs will be lower in climate zone 4 (the southern third of Illinois) because the IECC is less stringent in zone 4 than in zone 5.

The analysis concludes that homes built to meet the 2006 IECC requirements will save Illinois homeowners money by reducing long-term energy costs by far more than the construction-related cost increases. Annual heating and air conditioning cost savings for homes complying with the IECC in upstate Illinois would typically be around $160-470. Homeowners should generally realize a net positive cash flow within a few years after accounting for the effects of a typical mortgage. For these types of impacts to be achieved, an effort will be required to assist builders and subcontractors to comply with the code, and code officials to enforce it.

The analysis also shows a significant reduction in pollutant emissions. The reduction in pollution from sulfur dioxide is estimated to be 304 tons annually, resulting in cumulative reductions of 27,600 tons by 2020. Similarly nitrogen oxide reductions of 190 tons annually and cumulatively 17,300 tons by 2020 are estimated. Finally, carbon dioxide reductions of 141,000 tons annually are estimated and cumulatively 12.8 million tons by 2020.

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