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Pacific Northwest
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U.S. Department of Energy

Analysis of Energy Saving Impacts of New Residential Energy Codes for the Gulf Coast

RG Lucas

January 2007

Prepared for
U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99352

Summary

At the request of the Government Accountability Office (GAO), DOE's Building Energy Codes Program (BECP)[1] undertook an analysis of the energy savings and cost impacts associated with the use of newer and more efficient residential building energy codes in the states of Louisiana and Mississippi.

The intent of this analysis is to determine the potential energy and economic impacts from improved energy efficiency alternatives available for residential buildings during the Katrina reconstruction process. The focus is on new construction.

This analysis showed that going to an energy efficiency standard saved energy. Energy cost savings of 24% to 28% could be achieved by moving from estimated current practice for new construction to the 2006 International Energy Conservation Code (IECC) (International Code Council 2006). Furthermore, energy cost savings of 44% to 45% over current practice could be achieved by meeting Energy Star Home specifications.

[1] Pacific Northwest National Laboratory's (PNNL) Building Energy Codes Program is funded by the U.S. Department of Energy. PNNL is managed by Battelle Memorial Institute under DOE Contract DE-AC05-76RLO-1830.

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Tables

Whole Building Analysis

The whole building analysis examines energy used for space heating and air conditioning. Although there is additional potential to save energy used for water heating and appliances, those devices are preemptively regulated by Federal law and are not subject to state/local codes.

Assumptions

The assumptions and methodology used in the energy modeling are described below.

Simulation Model

The EnergyGauge simulation tool (Florida Solar Energy Center 1999) was used to estimate the savings from alternative energy efficiency scenarios. EnergyGauge utilizes the DOE-2 simulation model that estimates the building energy use for all 8760 hours in a year.

House Prototype

The house design considered was a 2000 ft^2 two-story house, 25x40 ft, with a slab-on-grade foundation. This area is slightly smaller than the average new site-built house, but larger than the average new multifamily unit or manufactured home. The window area is 332 ft^2 (15% window–to-wall area ratio) equally oriented north, south, east, and west. There are two doors with a total area of 40 ft^2. Heating with a natural gas furnace and central electric air conditioning are assumed. Electric resistance and electric heat pump heating are also briefly examined. Additionally, energy use estimates are generated for a house with a raised crawl space foundation. Heating, ventilation, and air conditioning (HVAC) equipment and ducts are assumed to be in the attic. Window U-factors were obtained from the Efficient Windows Collaborative. Duct area was obtained from the DOE's Building America Benchmarks (National Renewable Energy Laboratory 2004).

Energy Efficiency Alternatives

Five building level energy efficiency alternatives are examined—two baseline levels, a possible energy code level, and two "beyond-code" levels. The baseline is considered two ways. The first is an approximation of measures in typical *existing* housing in the rebuilding region. This baseline is heavily influenced by the older vintage housing in the area. The Energy Information Administration estimates that 38% of housing in the South Census Region were built prior to 1970; 58% were built before 1980; and 81% were built before 1989 (DOE 2006). The second baseline is estimated *current practice* for new

construction (assuming no code is in place)[2]. The latter approximately equates to the 1995 Model Energy Code (MEC) (International Code Council 1995), although much of current construction practice in the affected region is likely less energy efficient than is required by the 1995 MEC.

The third efficiency level is the 2006 International Energy Conservation Code. The 2006 IECC is the latest edition of that model code and is very similar in stringency to its 2003 predecessor, which is also a candidate for adoption in the affected states/counties. The fourth efficiency level is Energy Star Homes. Energy Star requires a 15% improvement over the IECC for all energy used in a house. Finally, the efficiency levels necessary to qualify for the $2000 Federal tax credit for energy efficiency new homes are examined. Qualification for the $2000 tax credit requires a 50% reduction in space heating and air conditioning energy use compared to the IECC.

In addition to the five whole-building efficiency levels, we also briefly examine two isolated efficiency measures in new homes: advantageous solar orientation and sealed (and tested) air distribution ducts. Finally, a number of isolated measures in retrofits to existing housing are examined.

There are different options available to comply with the IECC, Energy Star, and the tax credit. Additionally, the measures will vary somewhat based on the building design. The assumed methods here are likely to be commonly used and will keep the construction cost increases relatively low. The measures used here to comply with the IECC are <u>not</u> the same as the prescriptive measures in the IECC but rather comply via the code's performance path. Although the Energy Star Home program gives credit for improved lighting and appliances, it is assumed here for comparison purposes that the Energy Star option uses the same lights and appliances as the baseline and IECC scenarios; lights and appliances are briefly examined individually at the end of this report.

Tables 1 and 2 show the assumptions used in the energy analysis.

[2] There will be a variation of energy efficiency in both new and existing buildings. Some buildings may be more energy efficient than the baselines assumed here, some will be less (possibly much less, especially in existing housing).

Table 1. Comparison of the Baseline and other Energy Efficiency Alternatives

Selected Energy Features	Existing Housing Baseline	New Housing Baseline	IECC 2006	Energy Star	Tax Credit
Wall Insulation	R-13	R-13	R-13	R-13	R-13
Slab Insulation	None	None	None	None	None
Floor Insulation[1]	None	None	R-13	R-13	R-19
Roof Insulation	R-19	R-19	R-19[2]	R-30	R-30
Windows	Single[3] Aluminum (U-1.16, SHGC[4]-0.76)	Double[3] Aluminum (U-0.79, SHGC-0.68)	Double Vinyl with low-E (U-0.34, SHGC-0.30)	Double Vinyl with low-E (U-0.34, SHGC-0.30)	Double Vinyl with low-E (U-0.32, SHGC-0.28)
Doors	U-0.40	U-0.40	U-0.40	U-0.40	U-0.40
Lights and Appliances	Standard	Standard	Standard	Standard	Standard
Heating System	Gas Furnace 80% AFUE[5]	Gas Furnace 80% AFUE	Gas Furnace 80% AFUE	Gas Furnace 80% AFUE	Gas Furnace 90% AFUE
Cooling System	SEER-10[6]	SEER-13	SEER-13	SEER-13	SEER-15
Duct Insulation	R-4.0	R-4.0	R-8.0	R-8.0	R-8.0
Programmable Thermostat	No	No	No	Yes[7]	Yes[7]
Air Sealing	Standard	Standard	Standard	0.30 ACH (tested)	0.30 ACH (tested)
Duct Sealing	Standard	Standard	Standard	50 cfm leakage (tested)	50 cfm leakage (tested)

1. Floor insulation is applicable to crawlspace foundations, not slab-on-grade foundations.
2. The prescriptive requirement in the 2006 IECC for ceiling/roof R-value is R-30. A lower ceiling insulation R-value was traded off for higher window performance and higher efficiency heating equipment.
3. Single and double, with reference to windows throughout this report, means single and double glazing.
4. SHGC is solar heat gain coefficient
5. The Federal minimum Annual Fuel Utilization Efficiency (AFUE) requirement is 78%. A higher efficiency heating system was used in this simulation because 80% is the most commonly used efficiency level for new furnaces.
6. A 10 SEER was the most commonly used efficiency level before Federal minimum standards increased to 13 SEER in January 2006.
7. EnergyGauge assumes that the occupants will alter their thermostat settings to save energy (reducing comfort to some degree) if a programmable thermostat is used. There is no evidence to support this assumption.

Table 2 lists the specific improvements assumed in this analysis. Again, there are other options available for meeting the IECC, Energy Star, or tax credit qualification. The energy efficiency measures for the tax credit assumed here are similar to that for a real house in Jacksonville, Florida (a similar climate to New Orleans) that qualified for the tax credit (see http://www.resnet.us/taxcredits/examples/builder.aspx?BuilderID=1).

Table 2. Improvements for Energy Efficiency Alternatives

New Housing Baseline	Existing housing baseline plus double-paned windows and a 13 SEER air conditioner
IECC	New housing baseline plus double vinyl low-E windows, R-8 ducts
Energy Star	IECC plus R-30 ceiling insulation, improved duct and envelope sealing verified by testing, programmable thermostat
Tax Credit	Energy Star plus 15 SEER efficient air conditioner, 90% efficient furnace, U-0.32/SHGC-0.28 windows and, for crawl space foundation scenario only, R-19 floor insulation and U-0.20 doors

Climate/Location

This analysis uses the New Orleans climate. There is little variation in climate across the region affected by Katrina. Additionally, there is no climate data available in the EnergyGauge simulation model for any southern Mississippi cities.

Louisiana is adopting the 2006 International Residential Code (IRC) (ICC 2006). Mississippi is adopting the 2003 IRC as a voluntary code that counties have the option of adopting. The energy efficiency provisions in the 2006 IRC, the 2003 IECC, and 2006 IECC are essentially identical for the purposes of this analysis.

Energy Costs

A natural gas furnace for heating and a central air conditioner for cooling are assumed in the analysis. 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 averaged above $12 per thousand cubic feet (approximately equal to a million Btus) in the residential market last winter in Louisiana (DOE/EIA http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_SLA_m.htm) and about $16 per thousand cubic feet for Mississippi. Recent (October 2006) DOE fuel price Short Term Energy Outlook projections (DOE/EIA 2006 http://www.eia.doe.gov/emeu/steo/pub/8ctab.html) estimate residential natural gas prices in the East South Central and West South Central regions to be at $12 or $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 9.2 cents/kWh in Louisiana and 9.5 in Mississippi based on June 2006 prices in (DOE/EIA http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html). 9.2 cents/kWh was assumed in this analysis.

Energy Simulation Results

Table 3 shows the results of the energy simulations for a house with a slab-on-grade foundation and a gas furnace heating system. The electricity use is almost entirely for cooling though there is a small amount of fan energy use during heating season (1 kWh=3413 Btu or 0.003413 MBtu).

Table 3. Annual Energy Costs (Space Heating and Cooling Only) of Whole Building Alternatives – House with Slab-on-Grade Foundation

Efficiency Alternative	Cooling Cost	Heating Cost	Total Cost	Savings over New Housing Baseline	Electricity (kWh) and Natural Gas (MBtu) Use	
					kWh	MBtu
Existing Housing Baseline	$674	$206	$880	-$195 (-28%)	7436	16.3
New Housing Baseline	$520	$165	$685	--	5742	13.1
IECC	$379	$139	$518	$167 (24%)	4193	11.0
Energy Star	$291	$84	$375	$310 (45%)	3214	6.7
Tax Credit	$239	$75	$314	$371 (54%)	2627	6.0

Table 4 shows how the results vary by heating system type. These systems are all utilized in the Gulf Coast region, although heat pumps are apparently the least common of the three. Energy Star and the tax credit procedures allow electric resistance heating, but heavily penalize this heating system necessitating substantial improvements beyond what is required for other heating systems, so it is unlikely that electric resistance heating would be used for these alternatives. Furthermore, the package identified for the tax credit does not qualify when a heat pump is used instead of a natural gas furnace. With the high natural gas prices and the mild climate, an electric heat pump has lower heating costs than the natural gas furnace. Note the diminishing returns where the improved heating system saves less for the more efficient building alternative (and vice-versa).

Table 4. Annual Heating Costs by Fuel/Equipment Type

Efficiency Alternative	Natural Gas	Electric Resistance	Electric Heat Pump
Existing Housing Baseline	$206	$297	$155
New Housing Baseline	$165	$238	$128
IECC	$139	$201	$107
Energy Star	$84	--	$69
Tax Credit	$75	--	--

Table 5 shows results for a crawl space foundation rather than a slab-on-grade foundation. Both foundation types are common in the Gulf Coast region. A raised foundation such as a crawl space may be more common in low-lying areas prone to flooding.

Table 5. Annual Energy Costs (Space Heating and Cooling Only) of Whole Building Alternatives – House with Crawl Space Foundation

Efficiency Alternative	Cooling Cost	Heating Cost	Total Cost	Savings over New Housing Baseline	Percent Savings over New Housing Baseline
Existing Housing Baseline	$726	$314	$1040	-$212	-26%
New Housing Baseline	$562	$266	$828	--	--
IECC	$424	$171	$595	$233	28%
Energy Star	$342	$122	$464	$364	44%
Tax Credit	$281	$100	$381	$447	54%

Table 6 shows the impacts of specific improvements or reductions compared to the baseline for the new house with slab-on-grade foundation and natural gas heating. The improved orientation/shading scenario has 58% of the window area facing south, only one window on the east and west sides of the house, and 2-ft. overhangs on the north and south sides of the house. The sealed duct scenario has only 100 cfm duct leakage to the outside of the house when tested at a pressure of 25 Pascals.

Table 6. Annual Energy Costs (Space Heating and Cooling Only) of Specific Improvements or Reductions Relative to the New Housing Baseline

Efficiency Alternative	Cooling Cost	Heating Cost	Total Cost	Impact Vs. Baseline	Percent Impacts Vs. Baseline
New Housing Baseline	$520	$165	$685	--	--
Improved Orientation/Shading	$483	$158	$641	$44 savings	6% savings
Sealed Ducts	$471	$151	$622	$63 savings	9% savings

Economic Results

Tables 7 and 8 show an estimate of construction cost impacts for the various improvements examined above.

Table 7. Incremental Construction Costs

Improved Measure	Base Measure	Unit Cost	Total Cost	Source for Cost Data
Double Vinyl Windows with Low-E	Double Aluminum Windows	$1/ft^2	$332	Estimate from various sources. Cost increase is primarily from addition of low-E coating.
R-8 Duct Insulation	R-4	0.68/ft^2	$286	California DEER Database (Itron 2005)
R-30 Ceiling Insulation	R-19	0.33/ft^2	$330	R. S. Means Cost Data
Improved Duct Sealing	Standard duct sealing	$235	$235	California Energy Commission (2000)
Improved envelope sealing	Standard envelope sealing	--	$500	http://www.powerhousetv.com/stellent2/groups/public/documents/pub/phtv_se_we_gs_000530.hcsp
Home Energy Rating	--	--	$450[1]	http://www.nbnnews.com/NBN/issues/2006-05-22/Research/index.html http://www.hud.gov/offices/hsg/sfh/eem/eemhog96.cfm
Programmable Thermostat	Standard Thermostat	$65	$65	www.fypower.org/res/tools/products_results.html?id=100133
15 SEER efficiency Air Conditioner	13 SEER	$556	$556	California DEER database, 3.5 ton system
90% Efficient Gas Furnace	80% efficient furnace	$600	$600	California DEER database and other sources

1. It is not known how much or even if raters will charge extra if certification for the tax credit is included in their rating. Determination of qualification for the tax credit does not require extra effort beyond entering the information needed for a home energy rating in rating software.

Table 8. Incremental Construction Costs for Energy Efficiency Alternatives

	Improvements Over New Housing Baseline	Cost Increase
IECC	Double vinyl low-E windows R-8 Ducts Total	$332 $286 **$618** vs. Baseline
Energy Star	R-30 ceiling insulation improved duct sealing improved envelope sealing home energy rating programmable thermostat Total	$330 $235 $500 $450 $65 **$1580** vs. IECC **$2198** vs. Baseline
Tax Credit	14 SEER efficient air conditioner 90% efficient furnace U-0.32/SHGC-0.28 windows Tax credit Total	$556 $600 0[(a)] -$2000 **-$844** vs. Energy Star **$736** vs. IECC **$1354** vs. Baseline
(a) These windows are the same type (materials and technology) as used in the Energy Star house, but would require the builder to be more selective in finding more energy efficient windows in the range available for that window type.		

Because most houses are financed, consumers will be very interested in the financial impacts of mortgages, which 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.

X 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.

X Other rates and economic parameters:
- 7% nominal discount rate
- 28% marginal federal income tax (it is assumed that tax deduction for mortgage is utilized)
- 1% property tax
- 3% nominal inflation for fuel prices
- 30-year analysis period, no residual/salvage value.

Table 9 shows the impacts to consumers' cash flow resulting from IECC compliance. The up-front costs include the down payment, points, and loan fees.

Table 9. Incremental Impacts to Consumers' Cash Flow Accounting for Mortgage

	IECC vs. New Housing Baseline	**Energy Star vs. New Housing Baseline**	**Tax Credit vs. New Housing Baseline**
Up-Front Costs	$69	$247	$152
Annual Energy Savings	$167	$310	$371
Annual Mortgage and Tax Increase	$39	$140	$87
Net Annual Cash Flow Savings (excluding up-front costs)	$128	$170	$284
Time to Net Positive Cash Flow	½ year	1 ½ years	½ year
Discounted Present Value Benefit over 30-year Period	$2335	$3279	$5171

This report has focused on energy efficiency improvements in new residential buildings. Some residences damaged by Katrina will not need to be replaced completely but will only need renovations. Table 10 shows the estimated costs and energy savings of some opportunities for energy efficiency improvements that can occur in renovation projects.

Table 10. Costs and Energy Savings for Key Upgrades for Renovation Projects

From	To	Incremental cost	Energy cost savings	Energy savings
Single pane, aluminum window	Double pane, vinyl low-E window	$10.56/ft^2	$202	1576 kWh 4.7 MBtu gas
SEER-10 Cooling	SEER-13 Cooling	$335	$127	1390 kWh
Manual thermostat	Programmable thermostat	$65	Unknown[1]	Unknown[1]
Standard duct sealing	Improved duct sealing	$235	$63	542 kWh 1.1 MBtu
1. Studies have been unable to verify any energy savings from programmable thermostats (Energy Design Update, December 2006). EPA recently decided to cease crediting any thermostats as Energy Star. Inherently, these thermostats save no energy but allow the occupant to set a temperature schedule that could reduce energy use.				

The window cost in Table 10 is from the *2006 Gulf Coast Reconstruction Estimator* (Craftsman Book Company 2006) for a 4 ft. by 4 ft. sliding window. Based on this particular cost data, the payback from improved windows may not appear attractive. However, single-pane windows can have substantial disadvantages that are not accounted for in building energy simulations. The inner surface temperature of a single-pane aluminum window will become quite low during the coldest winter conditions. This can result in an unpleasant drafty feeling for occupants in the vicinity of the windows. Also, the cold surface can lead to possible water condensation which could eventually result in water damage to the windows or walls over the long run.

The cost of the improved air conditioner efficiency in Table 10 is from the Federal Register (May 23, 2002, Vol. 67, p. 36367).

Lighting and Appliances

This report has examined energy saving opportunities for space heating and cooling only. A brief estimate of potential savings from improved lighting and appliances is provided below in Table 11.

Table 11. Costs and Energy Savings for Lighting and Appliance Upgrades

From	To	Incremental cost	Energy cost savings	Energy savings
Standard lighting	More efficient lighting	$99 ($4.97/fixture)	$48	530 kWh
Refrigerator – conventional (new)	Energy Star	$65	$9	98 kWh
Clothes Washer – conventional (new)	Energy Star	$440	$59	322 kWh if water heater is by electricity 1.7 MBtu if water heater is by gas
Dish Washer – conventional (new)	Energy Star	$45	$13	107 kWh if water heating is by electricity, 0.4 MBtu and 47 kWh if water heating is by gas

Lighting

Lightings cost are from the California 2004-05 Database for Energy Efficiency Resources, Ver. 2.01, line 603 of EXCEL database, 23 watt integral CFL replacing 100 watt incandescent (http://eega.cpuc.ca.gov/deer/). Assuming a house has a total of 20 fixtures, the Energy Star Advanced Lighting Package minimum requirements would save $48 a year in electricity for lighting. Lighting savings are from the Energy Star Customizable Savings Calculator: (http://www.energystar.gov/index.cfm?c=fixtures.pr_light_fixtures).

Appliances

All the appliance savings in Table 11 are relative to the minimum efficiency appliance at the *current* Federal manufacturing minimum standards. If the appliances are to replace older appliances that may be much less efficient, the savings can increase considerably. Manufacturers can qualify for tax credits for energy efficiency appliances, which should be passed on to consumers (see http://www.energytaxincentives.org/tiap-appliances.html).

The refrigerator, clothes washer, and dish washer costs below are all the midrange cost from Energy Star web pages listed within each subsection below.

Refrigerator

An Energy Star compliant refrigerator is at least 15% more energy efficient than Federal manufacturing minimum standards. This is estimated to save $9 a year over a new non-Energy Star refrigerator (http://www.energystar.gov/ia/partners/reps/pt_reps_res_retail/files/retail_annual_savings.pdf). Savings from replacing an older refrigerator can be much higher; for example $65 annual savings over a pre-1993 refrigerator (http://www.energystar.gov/ia/partners/manuf_res/downloads/Refrigerator_Partner_Resource_Guide.pdf). The manufacturer tax credit ranges from $75 per refrigerator for exceeding Federal standards by 15% to $175 for exceeding Federal standards by 25%.

Clothes Washer

The annual energy cost savings is estimate to be $59 (http://www.energystar.gov/ia/partners/manuf_res/downloads/ClothesWasher_Partner_Resource_Guide.pdf). $32 of this savings is from reduced water usage and $27 is from reduced energy usage. The manufacturer tax credit is $100.

Dish Washer

The Energy Star dishwasher web site reported to save an average of $13 a year, with about $4 of the savings coming from reduced water usage. (http://www.energystar.gov/ia/partners/manuf_res/downloads/Dishwasher_Partner_Resource_Guide.pdf). The manufacturer tax credit is $32.31.

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