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TEXAS' SENATE BILL 5 LEGISLATION FOR REDUCING POLLUTION IN NON-ATTAINMENT AND AFFECTED AREAS: PROCEDURES FOR MEASURING ELECTRICITY SAVINGS FROM THE ADOPTION OF THE INTERNATIONAL ENERGY CONSERVATION CODE (IRC/IECC 2001) IN NEW RESIDENCES.

A Report Prepared for:

The Texas Natural Resource Conservation Commission

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ABSTRACT

Four areas in Texas have been designated by the EPA as non-attainment areas because ozone levels exceed the NAAQS maximum allowable limits, Beaumont-Port Arthur, El Paso, Dallas-Ft. Worth, and Houston-Galveston-Brazoria. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits (i.e., affected areas), including: Austin, Corpus Christi, San Antonio, and the Longview-Tyler-Marshall area.

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the TNRCC, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.).

An important part of this legislation is the evaluation of the State's energy efficiency programs, which includes reductions in energy use and demand that are associated with specific energy conservation measures. This paper outlines the procedures that are being developed to report the electricity savings associated with the adoption of the International Energy Conservation Code (IECC 2001) in residential construction in non-attainment and affected counties. These electricity savings will then be converted to NO_x reductions using the appropriate state-wide, utility grid conversion model.

INTRODUCTION

The Federal Clean Air Act of 1970 authorized the United States Environmental Protection Agency (EPA) to establish the maximum allowable concentrations of pollutants that are known to endanger human health, harm the environment or cause property damage. In response to this act the EPA established National Ambient Air Quality Standards (NAAQS) which describe the allowable maximum limits of the six primary pollutants: carbon monoxide (CO -- 9 ppm, 8 hr avg.), lead (Pb -- 1.5 ppm, maximum quarterly average), oxides of nitrogen (NO_2 -- 53 ppb annual average), Ozone (O_3 -- 120 ppb, 1 hr, avg.), particulate matter (PM_{10}-- 50 micrograms/m^3 annual average), and sulfur dioxide (SO_2 -- 30 ppb annual average). In Texas the Texas Natural Resource Conservation Commission (TNRCC) has the responsibility of measuring and reporting these emissions to the EPA.

Four areas in Texas have been designated by the EPA as non-attainment areas because ozone levels exceed the NAAQS maximum allowable limits, Beaumont-Port Arthur, El Paso, Dallas-Ft. Worth, and Houston-Galveston-Brazoria. The El Paso area also violates the NAAQS maximum allowable limits for carbon monoxide and respirable particulate matter. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits, including: Austin, Corpus Christi, San Antonio, and the Longview-Tyler-Marshall area. Ozone is formed when oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and oxygen (O_2) combine in the presence of strong sunlight. Unfortunately, in hot and humid areas such as the Houston-Galveston-Brazoria triangle, 40 to 60 ppb of the summertime ozone can be attributed to biogenic sources (i.e., plants, lightning, and down-mixing of the stratospheric ozone). Hence, reducing manmade emissions of ozone in these regions becomes even more important.

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the TNRCC, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.). An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC 2001). This paper outlines the procedures that are being developed to report the emission reductions associated with the adoption of the International Energy Conservation Code (IECC 2001) in non-attainment and affected counties.

BACKGROUND

Thirty-eight counties in Texas have been designated by the EPA as either non-attainment or affected areas. These areas are shown on the map in Figure 1, as non-attainment (pink-shaded), and affected (green-shaded). The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

These counties represent different areas of the state that have been categorized into the different climate zones by the 2001 IECC[1] as shown in Figure 2, namely, climate zone 5 or 6 (i.e., 2,000 to 2,999 HDD_{65}) for the Dallas-Ft. Worth and El Paso areas, and climate zones 3 and 4 (i.e., 1,000 to 1,999 HDD_{65}) for the Houston-Galveston-Beaumont-Port Author-Brazoria area. Also shown on Figure 2 are the locations of the various weather data sources, including the seventeen Typical Meteorological Year (TMY2) (NREL 1995), and four Weather Year for Energy Calculations (WYEC2) (Stoffel 1995) weather stations, as well as the forty-nine National Weather Service weather stations, (NWS) (NOAA 1993).

To no surprise, these thirty eight counties represent some of the most populated counties in the state, and contained 13.9 million residents in 1999, which represents 69.5% of the state's 20.0 million total population (U.S. Census 1999). As shown in Figure 3, three of these counties (i.e., Harris, Dallas, and Tarrant), are non-attainment counties. The fourth county, Bexar county, is classified as an affected county. These four counties contain 8.0 million residents, or 40.0% of the state's total population. In the rankings of the remaining counties it is clear to see that the most populated counties also represent the majority of the non-attainment regions.

In Figure 4 the total housing units trends in the non-attainment and affected counties is shown to closely follow the county populations, with Harris, Dallas, Tarrant, and Bexar counties containing 3.2 million housing units, or 40.0% of the state's total 8.0 million households (U.S. Census 1999). However, in Figure 5 the 1999 residential building permit activity differs from the population and total housing unit trends, with the most activity occurred in Harris county (25,862 units), followed by significantly less construction in the five counties in the 10,000 to 15,000 unit range, including Dallas, Travis, Bexar, Collin and Tarrant counties. These six counties represented 88,833 housing starts, or 71% of the total 125,100 residential building permits in the 38 counties classified as non-attainment or affected by the EPA.

[1] The "2001 IECC" notation is used to signify the 2000 IECC (IECC 2000) as modified by the 2001 Supplement (IECC 2001), published by the ICC in March of 2001, as required by Senate Bill 5.

Also of interest in Figure 5 is the significant number of new multi-family units in the counties with the largest number of building permits. In the six largest counties (i.e., Harris, Dallas, Travis, Bexar, Collin and Tarrant) there were 34,038 new multi-family units, or 38% of the 88,833 housing starts in these counties. The map in Figure 6 shows these fast growing areas to be primarily in four metropolitan areas: the Houston area containing the fastest growing county (Harris county), the Dallas-Ft.Worth area containing four of the six counties (Dallas, Collin, Tarrant, and Denton), Travis county in the Austin metropolitan area, and Bexar county in the San Antonio area.

METHODOLOGY

Senate Bill 5 will allow the TNRCC to obtain emissions reduction credits for reductions in electricity use and electric demand that are attributable to the adoption of the International Energy Conservation Code (IECC 2001) in non-attainment and affected counties. In order for the TNRCC to accomplish this county-wide reductions in electricity use must be calculated by the ESL and presented to the TNRCC in a suitable format for calculating emissions reductions using a state-wide, utility grid conversion model. The methodology to accomplish this for residential buildings is presented in Figures 7 - 11. This methodology is composed of several procedures that will calculate and verify savings using several different sources of information. These procedures include:

1. The calculation of electricity savings and peak demand reductions from the implementation of the IECC 2001 in new residences in non-attainment and affected counties as compared against 1999 housing characteristics (IECC 2001 residential emissions reductions) using calibrated simulation.
2. A cross-check of the calculated energy use[2] against the published average energy use found in the USDOE's Residential Energy Characteristics Survey (RECS 1999)
3. A cross-check of electricity savings using a utility bill analysis method.
4. A cross-check of construction data using on-site visits.

Calculation of emissions reductions.

The primary procedure for calculating the emissions reductions from the adoption of the IECC 2001 in new residences is shown in Figures 7 and 8. Figure 7 is a flowchart of the overall procedure, which includes the information obtained from Figure 8. For each county, 1999 and 2002 residential housing characteristics will be ascertained according to the procedures in Figure 8. Using simulation, these characteristics are entered into the DOE-2 simulation to calculate the annual energy use of two average-sized residences, one representing the house with the average 1999 characteristics, and one representing the appropriate characteristics from the 2001 IECC. The annual electricity use of the 2001 IECC simulation is then subtracted from the annual electricity use of the similarly-sized 1999 residence to obtain the annual

electricity savings, and peak electric demand savings. Natural gas savings associated with space heating and the heating of domestic hot water would be calculated for informative purposes. The electricity savings attributable to the 2001 IECC energy conservation options would then be converted to NO_x reductions per house using the appropriate state-wide, utility grid conversion model. Electricity savings would then be scaled to represent the county-wide savings by multiplying the annual residential building permits for each county. Total NO_x reductions associated with the implementation of the 2001 IECC would then be calculated simultaneously for all non-attainment and affected counties using a state-wide conversion model.

In Figure 8 the detailed flowchart is shown for calculating the 2002 annual energy use of new residential construction for houses with and without the energy conserving features contained in the IECC 2001, chapters 4 and 6. This is accomplished with two separate calculations: a) one path that represents the standard house defined in the 2001 IECC chapter 4 and 5, that uses average housing characteristics for houses built in 1999 (left side of figure); and b) a second path that represents the standard house defined by the 2001 IECC that includes the energy conserving features[3] defined in chapter 4, 5 and 6 (right side of figure).

Calculating baseline energy use of new construction. The procedure for calculating the 2002 baseline residential energy consumption (left side of Figure 8) begins with the definitions of the standard house found in Chapter 4 of the 2001 IECC. These definitions are used to create a standard input file for the DOE-2 simulation program (LBNL 2000). This standard input file is then adjusted to reflect the average 1999 construction characteristics for each county[4] for type A-1 (single family) and type A-2 (all others) housing. The annual electricity and natural gas consumption for the average house[5] is then simulated using the DOE-2 program and the appropriate weather data[6] for each location. The annual, countywide, baseline energy consumption for new houses built in 2002 with characteristics that reflect the 2001 IECC and 1999 published data is calculated by multiplying the annual simulated energy use for an average house times the projected A-1 and A-2 county-wide housing permits for 2002. The projected A-1 and A-2 housing permits for each county are projected using multiple linear regression that utilizes countywide population growth and housing permits as shown in Figure 8. This baseline represents the expected annual energy use of all new construction in each county had those houses been constructed with the 2001 IECC chapter 4 and 5 "standard house" and average 1999 characteristics.

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[2] This energy use reported by RECS represents the total energy use, which would include electricity use and natural gas use.
[3] The energy conserving features in the IECC 2001 are the same as those contained in chapter 11 of the 2000 IRC, as modified by the 2001 Supplement (IECC 2001).
[4] The average 1999 construction characteristics represent the published data from several sources, including NAHB (2002), F.W. Dodge (2002), RECS (1999) and LBNL (1995).
[5] The average house size for each county is determined from published RECS (1995) data.
[6] The appropriate weather data for each county is the nearest TMY2 weather file that most accurately represents the 2001 IECC climate zone as shown in Figure 2.

Calculating code-compliant energy use of new construction. The procedure for calculating the code-compliant 2002 residential energy consumption (right side of Figure 8) also begins with the definitions of the standard house found in Chapter 4 and 5 of the 2001 IECC. This code-compliant input file reflects the average 1999 house size[7] for each county and IECC Chapter 5 or 6 construction characteristics[8] for type A-1 (single family) and type A-2 (all others) housing. The annual electricity and natural gas consumption for a code-compliant house is then simulated using the DOE-2 program and the appropriate weather data for each location. The annual, countywide, code-compliant energy consumption for new houses built in 2002 with code-compliant characteristics is calculated by multiplying the annual simulated energy use for a code-complaint house times the projected A-1 and A-2 housing permits for 2002. This code-compliant use represents the expected annual energy use of all new code-complaint construction in each county. The total electricity savings which can be attributed to the adoption of the IECC 2001 are then calculated by comparing the difference in annual energy use of the baseline housing versus the code-compliant housing as shown in Figure 7.

Reconciliation of the total savings.

Several procedures have been identified to reconcile the savings calculations, including:

a) a cross-check of the calculated energy use against the published average energy use found in the USDOE's Residential Energy Characteristics Survey (RECS 1999) as shown in Figure 9;
b) a cross-check of energy savings using a utility bill analysis method as shown in Figure 10; and
c) a cross-check of construction data using on-site visits as shown in Figure 11.

Cross-check of the calculated energy use against published data. The procedure to cross-check the calculated energy use of the baseline houses and code-compliant houses against the average energy use published by the RECS (1999) is shown in Figure 9. It is important to note that this procedure is proposed for informative purposes, since exact agreement between the housing characteristics in the IECC 2001 and RECS is not anticipated, since the RECS data reflects actual average occupant behavior, and the IECC reflects a controlled occupant behavior. The procedure multiplies the expected number of A-1 and A-2 housing units times the average annual energy use per household published in RECS to obtain the county-wide annual energy use for all newly constructed houses. This value is expected to be useful in judging whether or not any adjustments are needed in the 2001 IECC Chapter 4 and 5 construction characteristics.

Cross-check of energy savings using utility bill analysis. The energy savings attributable to the adoption of the 2001 IECC will reconciled with monthly utility billing data using the well-known Princeton

[7] Uses the same average house size for each county as determined from published RECS (1995) data.
[8] These characteristics include insulation levels, glazing type, etc., as defined in Chapter 6 of the 2001 IECC or Chapter 11 of the 2001 IRC.

Scorekeeping Method (PRISM) (Fels 1986; Fels et al. 1995) as shown in Figure 10. In general, the difference between average 1999 and 2002 utility bills should decrease by an amount that is similar to the calculated savings from 2001 IECC adoption for similar sized houses, with equal numbers of occupants, in similar neighborhoods. In Figure 10 the procedure for accomplishing this is set forth. The procedure has two parallel paths, one for the 1999 housing stock (left side of Figure 10) and one for the 2002 housing stock (right side of Figure 10).

For the housing cross-check with utility billing data, the procedure begins by selecting a 1999 house and a 2002 house that have similar characteristics to the construction characteristics that were used for the primary calculation shown in Figure 7 and 8. For each house 12 months of utility billing data are obtained and analyzed with PRISM. The resultant, valid parameters from PRISM[9] are then normalized by conditioned area to obtain a weather-normalized, averaged energy use per square foot. After the appropriate number of houses have been analyzed that represent a statistically significant sample of houses constructed in 1999 for each county (or for 2002), the Normalized Annual Consumption (i.e., NAC_{1999} expressed as kWh/yr-ft^2) is compared against the similar parameter for houses constructed in 2002 (i.e., NAC_{2002} expressed as kWh/yr- ft^2) to obtain the average electricity savings per square foot of conditioned area. This difference is then multiplied by the number of houses constructed in 2002 and the average conditioned area of the houses constructed in 2002 to obtain the total annual electricity savings per county. This total, county-wide, annual electricity savings calculated by utility bill analysis can then be compared to the total, county-wide, annual electricity savings calculated by simulation (i.e., Figures 7 and 8). For each county, savings from the difference in 1999 versus 2002 utility bills are expected to be similar to savings calculated by simulation for similar houses, with similar household characteristics[10].

Cross-check of construction data using on-site visits.

A reconciliation will also be carried out to cross-check selected parameters for both the 1999 and 2002 housing characteristics for each county as shown in Figure 11. For the 1999 housing stock, on-site surveys of a statistically significant sample will be used to cross-check the average building characteristics[11] used to simulate the average house in each county. Adjustments can then be made to the average 1999 characteristics should significant differences be found.

As shown in the right side of Figure 11, a similar procedure will be carried out for houses constructed in 2002 to determine if the on-site housing characteristics meet, or exceed the 2001 IECC. However,

[9] The primary parameter of interest from the PRISM analysis is the Normalized Annual Consumption (NAC). The goodness of fit indicators used to determine a valid PRISM run include the CV(NAC), and PRISM's adjusted R^2.
[10] If necessary, a similar procedure can be used to cross-check heating savings with either a 5 parameter change-point model using monthly electricity utility bills, or a PRISM model applied to monthly natural gas utility bills.
[11] As previously mentioned the 1999 average building characteristics represent the average characteristics published by NAHB, F.W. Dodge and LBNL.

differences found in the 2002 characteristics will be noted as to whether or not these differences represent characteristics that are less stringent or more stringent than code. Characteristics that are less stringent that code will be communicated with code officials to determine how procedures to the code need to be modified to better meet code requirements. Characteristics that are more stringent than code will be credited to the countywide energy savings as above code savings.

SUMMARY

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to reduce ozone levels by encouraging the reduction of emissions of NO_x by including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.). This paper has outlined the methodology that is being developed to report the electricity savings associated with the adoption of the International Energy Conservation Code (IECC 2001) in residential construction in non-attainment and affected counties. These electricity savings will then be converted to NO_x reductions using the appropriate state-wide, utility grid conversion model.

This methodology is composed of several procedures that will calculate and verify savings using several different sources of information. These procedures include the calculation of electricity savings from the implementation of the IECC 2001 in new residences in non-attainment and affected counties using calibrated simulation; a cross-check of the calculated energy use against the published average energy use found in the USDOE's RECS; a cross-check of energy savings using a utility bill analysis method, and a cross-check of construction data using on-site visits.

Similar methodologies are also under development for the calculation and reporting of electricity savings associated with the adoption of the International Energy Conservation Code (IECC 2001) in commercial and industrial construction in non-attainment and affected counties, the use of renewable fuel sources and the calculation and reporting of emission reductions associated with Texas Public Utility Commission's (PUC) Standard Offer Programs (SOPs), and Market Transformation Programs (MTFs), funded under Senate Bill 5 and 1999 Senate Bill 7.

ACKNOWLEDGEMENTS

Funding for this work has been provided by the State of Texas, under Senate Bill 5. The authors would also like to acknowledge the significant contributions of Mr. Mushtaq Ahmad who provided assistance with the DOE-2 programming, Ms. Vivian Yu who provided assistance with programming, and Mr. Piljae Im (Im 2002), whose M.S. Thesis contains a detailed reference of the procedures and example calculations.

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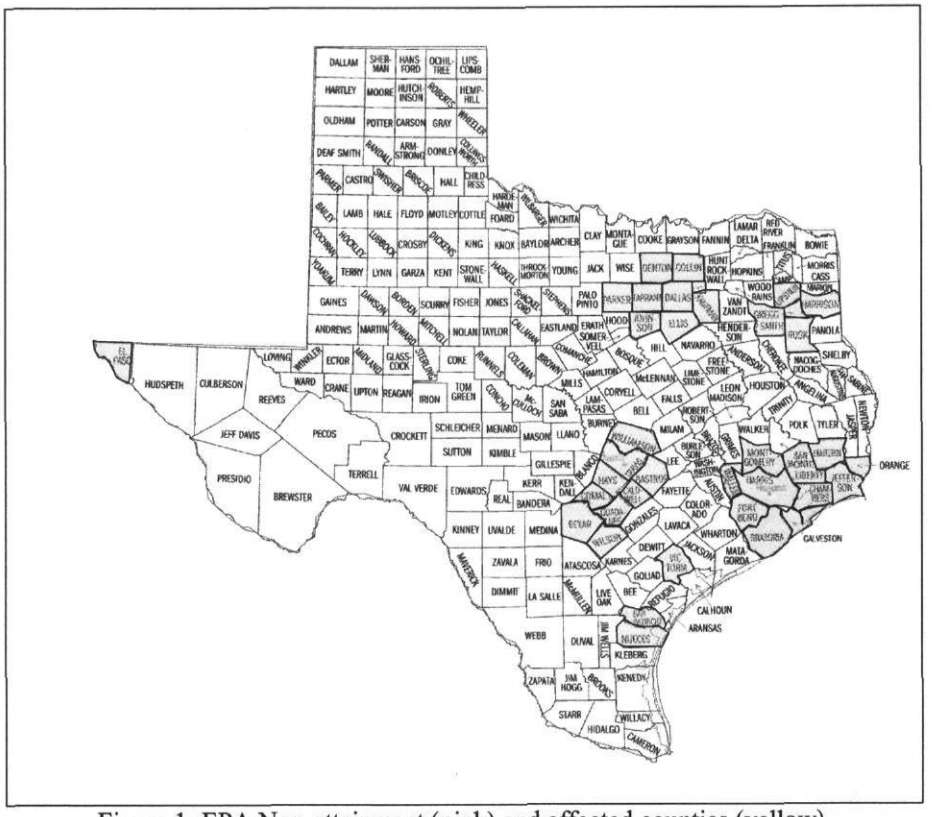

Figure 1: EPA Non-attainment (pink) and affected counties (yellow).

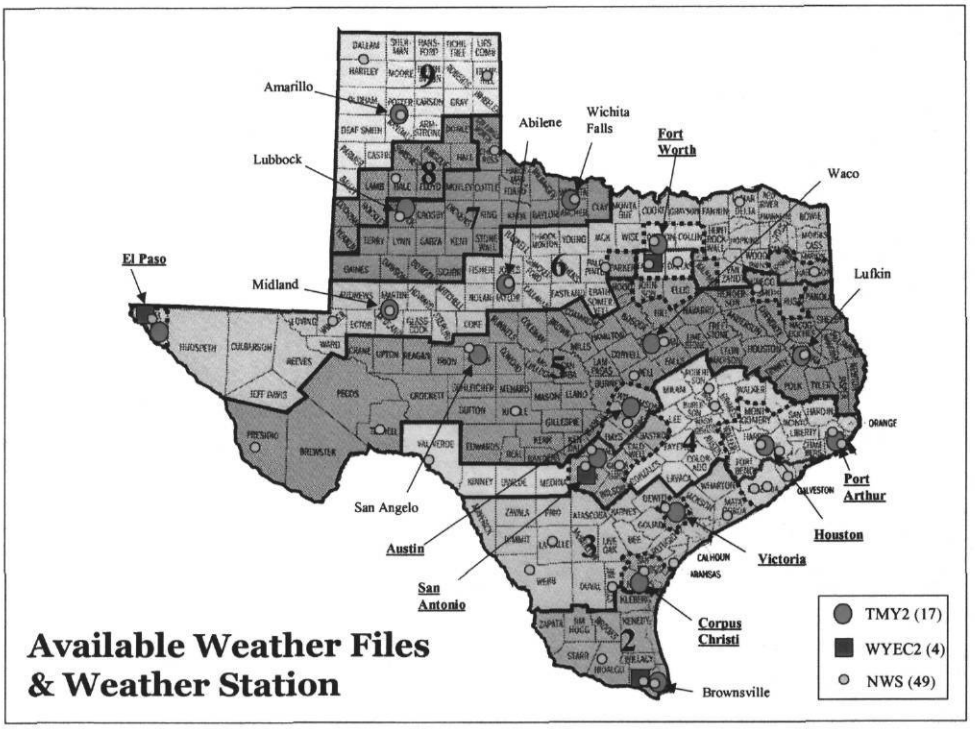

Figure 2: Available NWS, TMY2 and WYEC2 weather files compared to IECC weather zones for Texas.

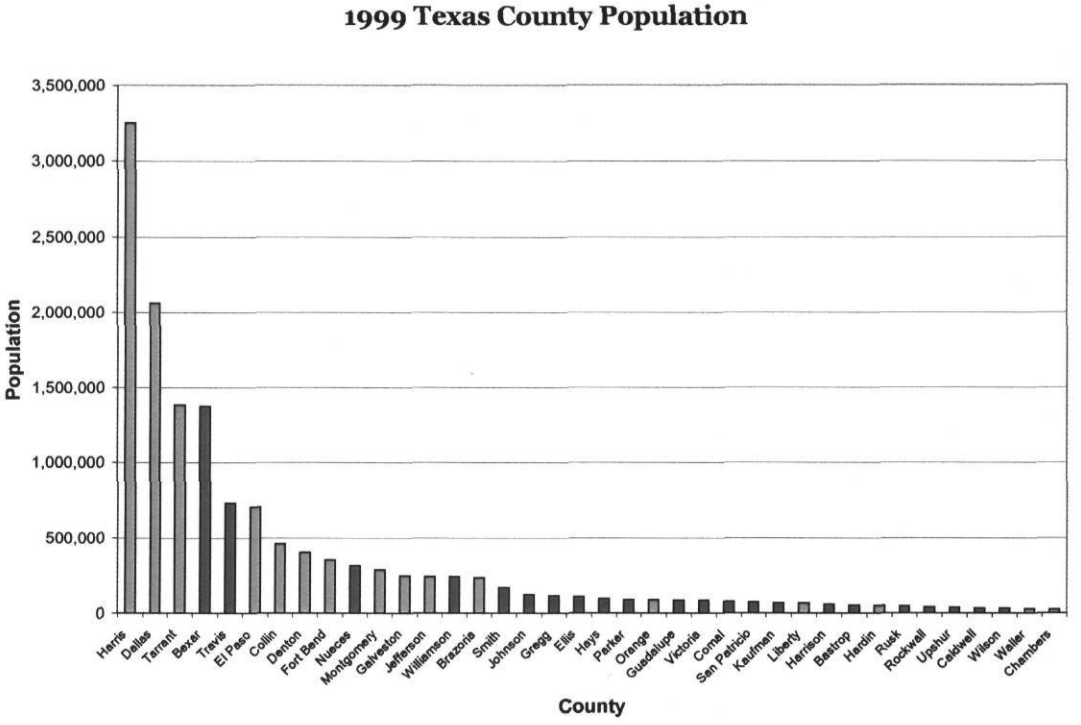

Figure 3: 1999 Texas county population for non-attainment (pink) and affected (green) counties (Source: U.S. Census)

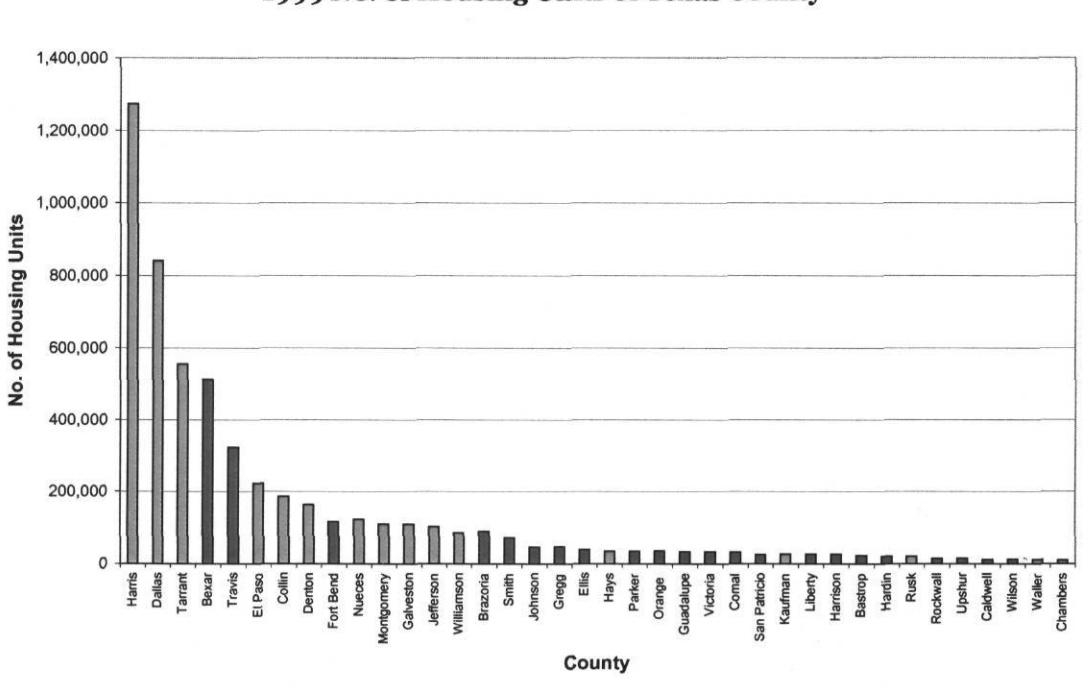

Figure 4: 1999 Housing Units by County (Source: RECenter 2002).

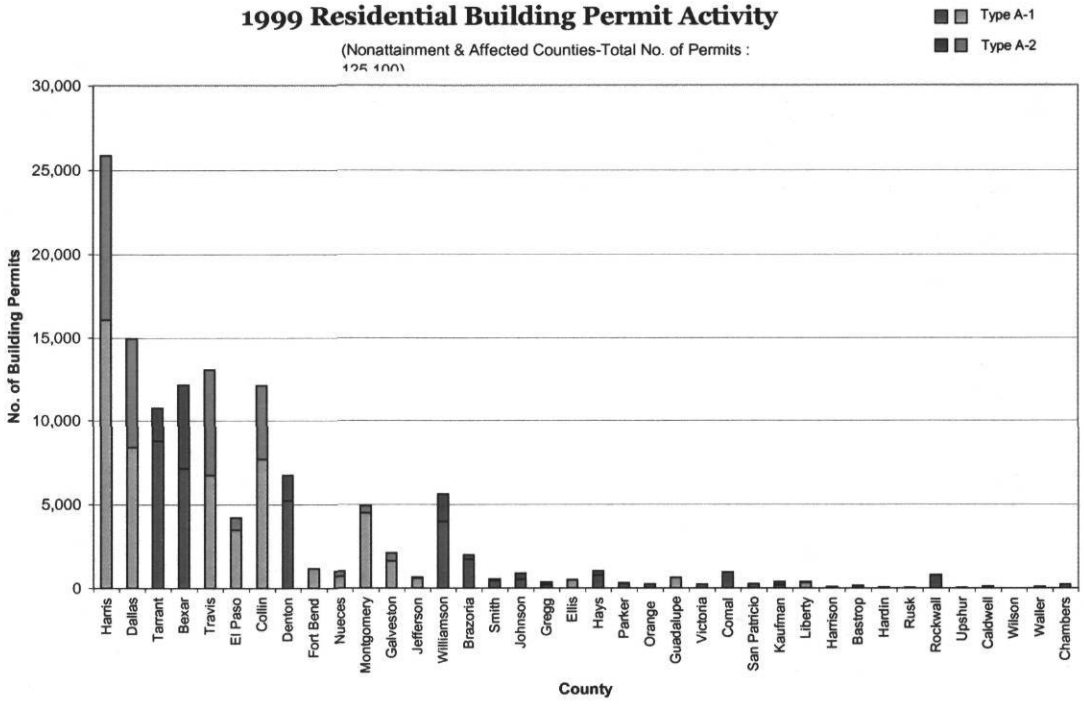

Figure 5: 1999 Residential Building Permits by County (Source: Real Estate Center, TAMU).

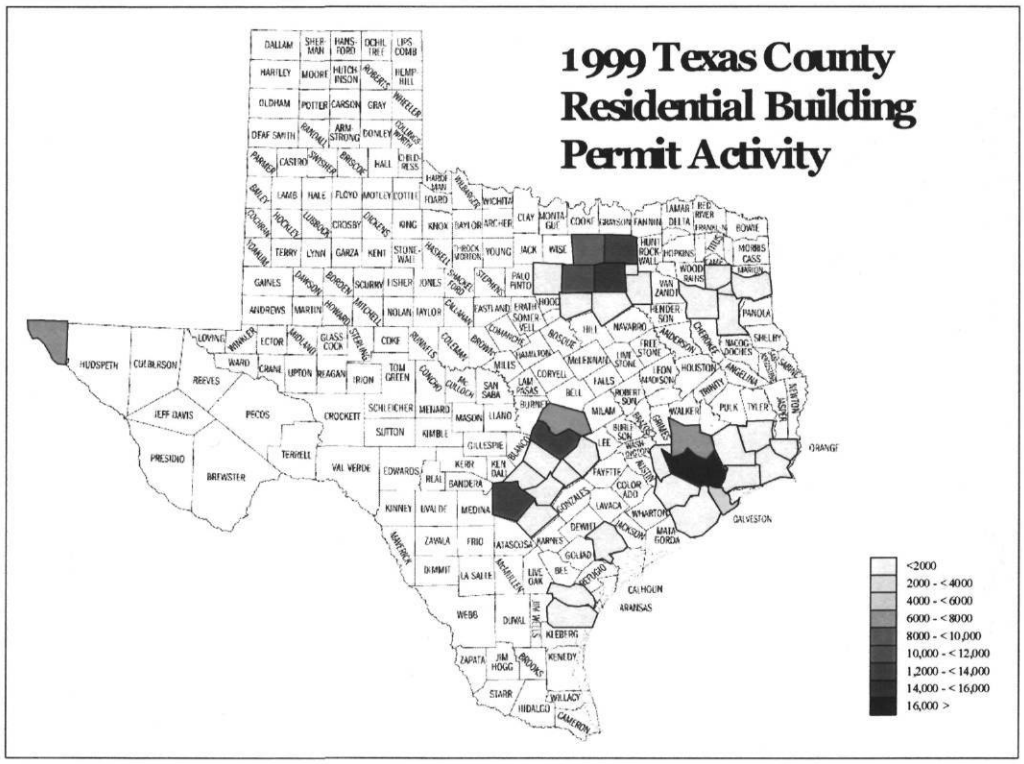

Figure 6: Map of 1999 Residential Building Permits by County (Source: Real Estate Center, TAMU).

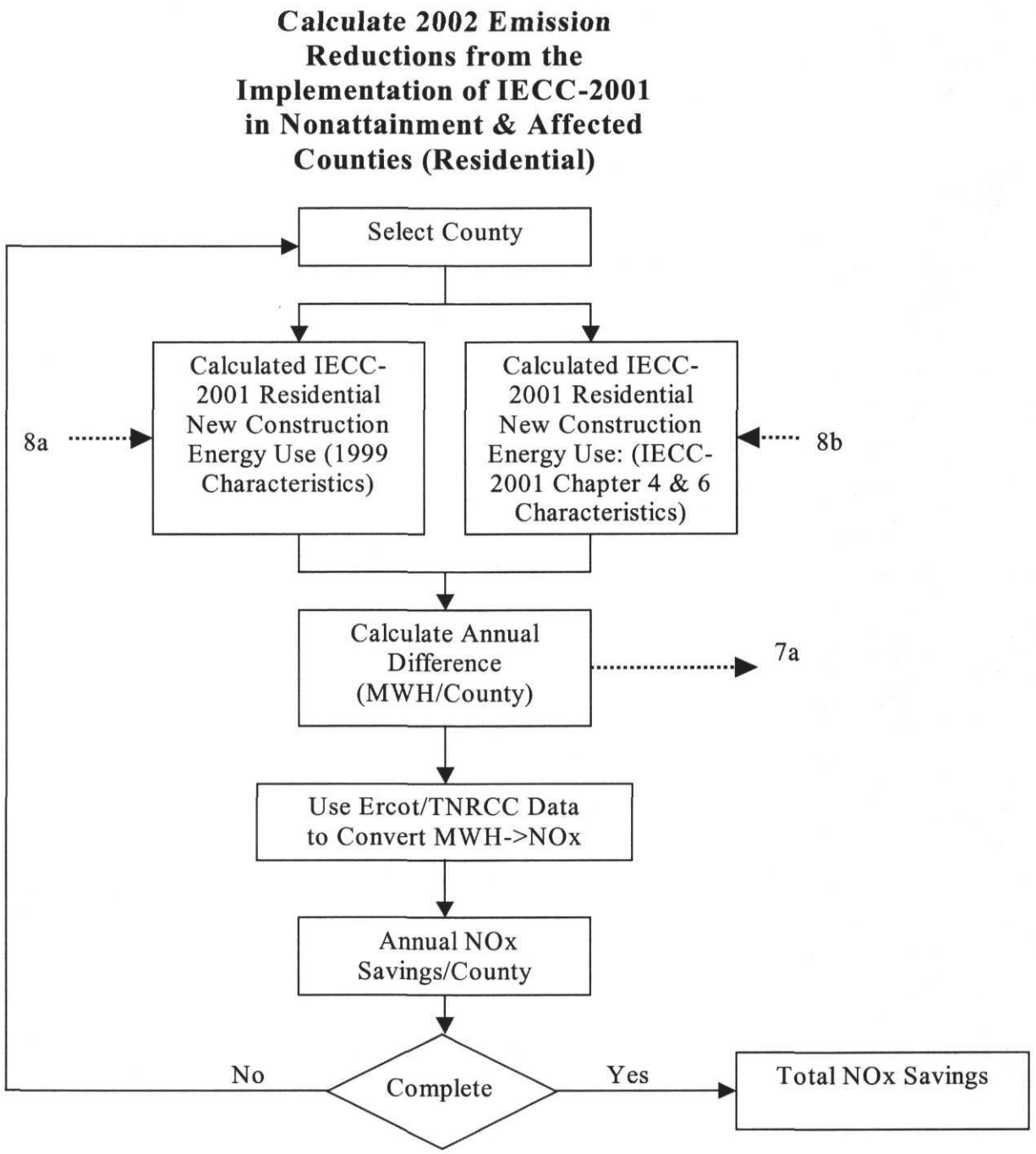

Figure 7: Overall General flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.

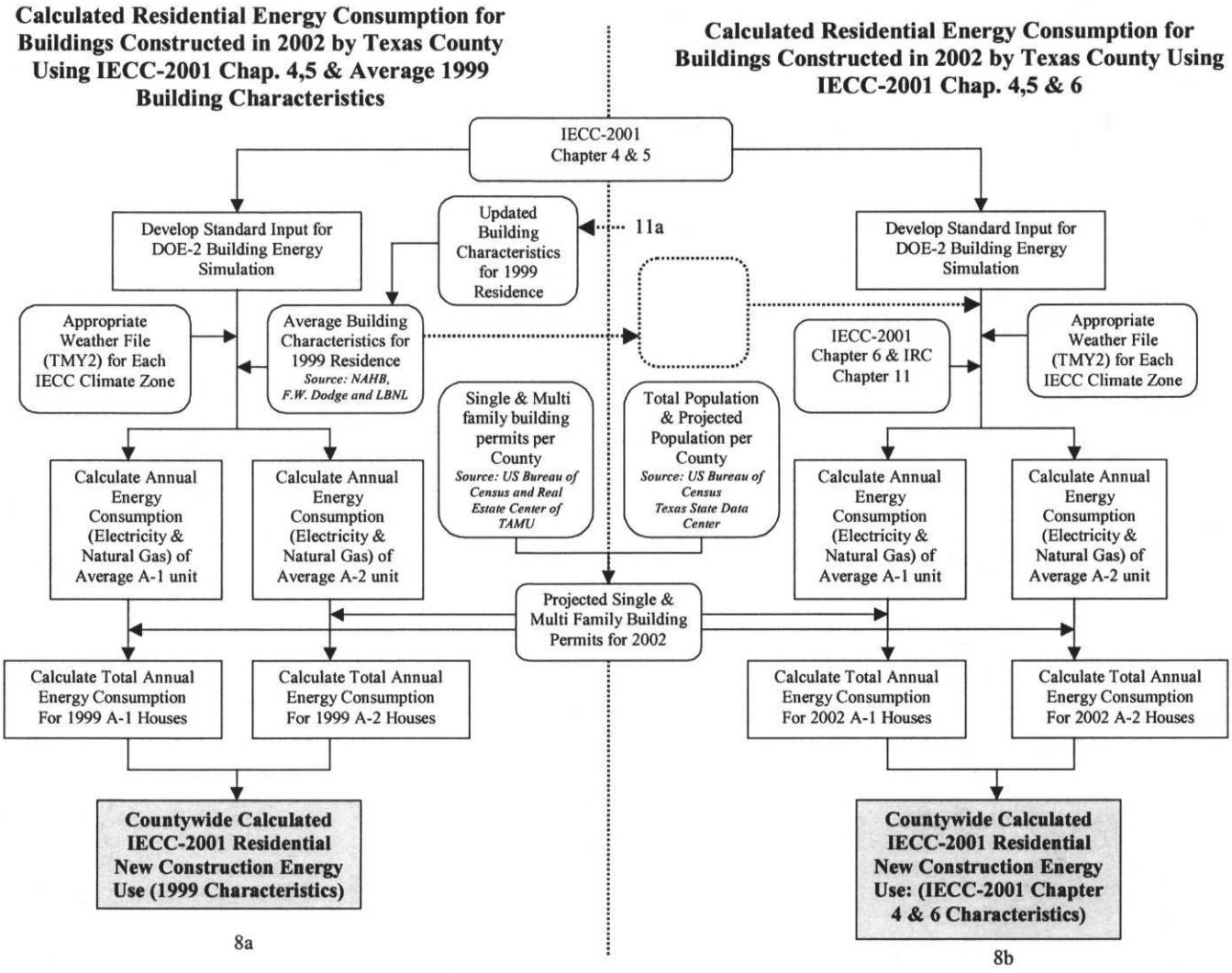

Figure 8: Calculation of countywide residential new construction energy consumption (1999 characteristics and 2001 IECC/IRC).

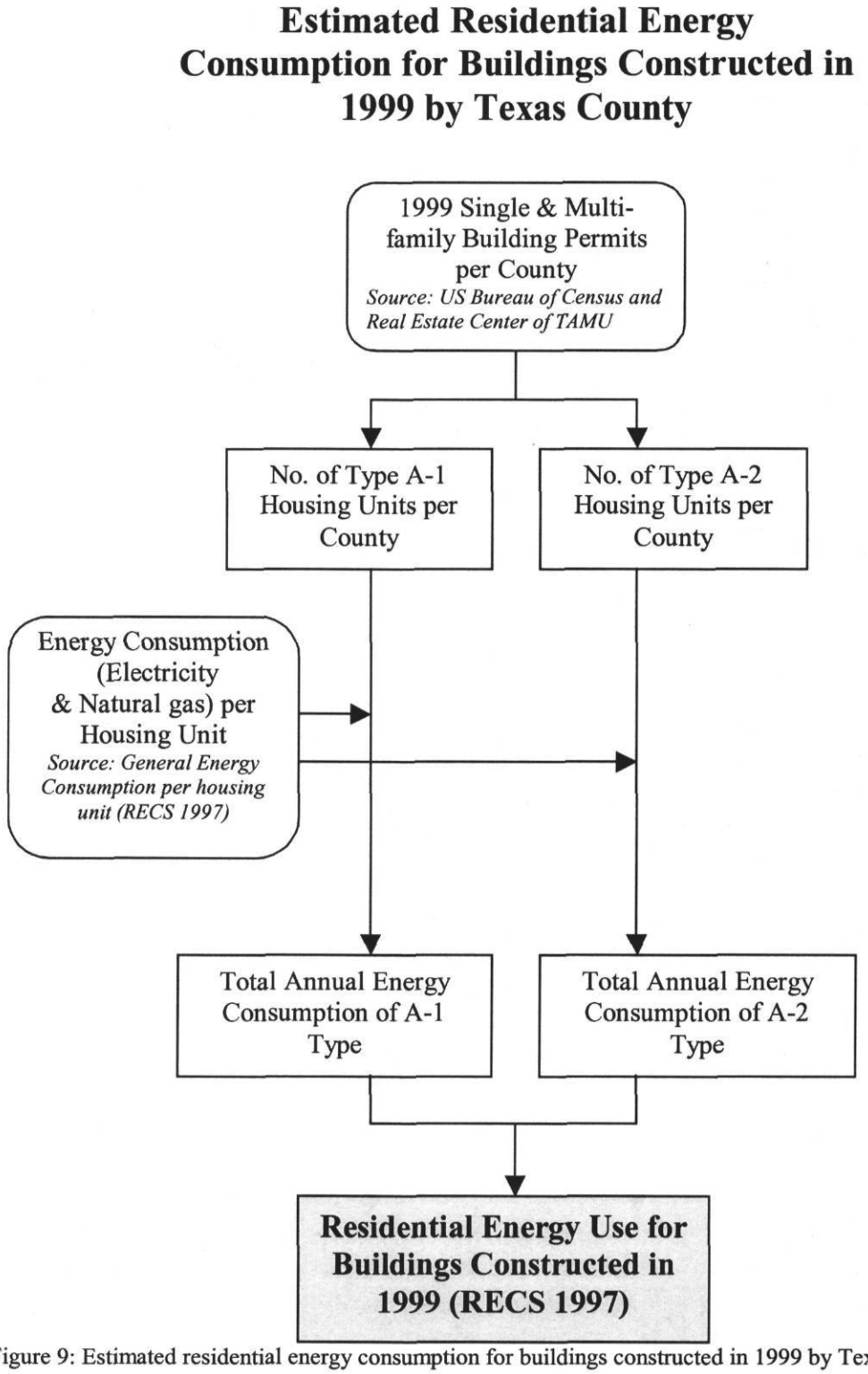

Figure 9: Estimated residential energy consumption for buildings constructed in 1999 by Texas county.

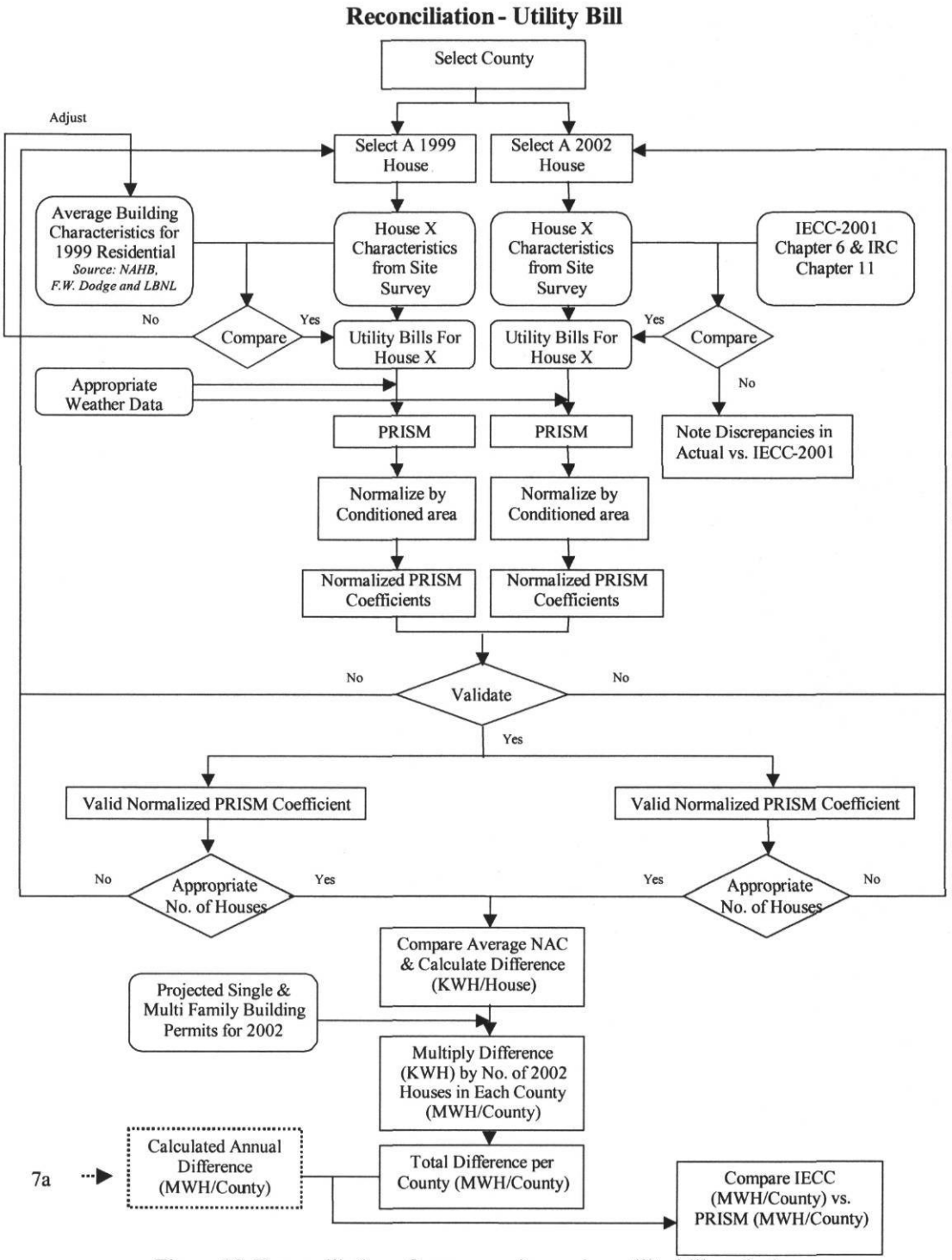

Figure 10: Reconciliation of energy savings using utility bill analysis.

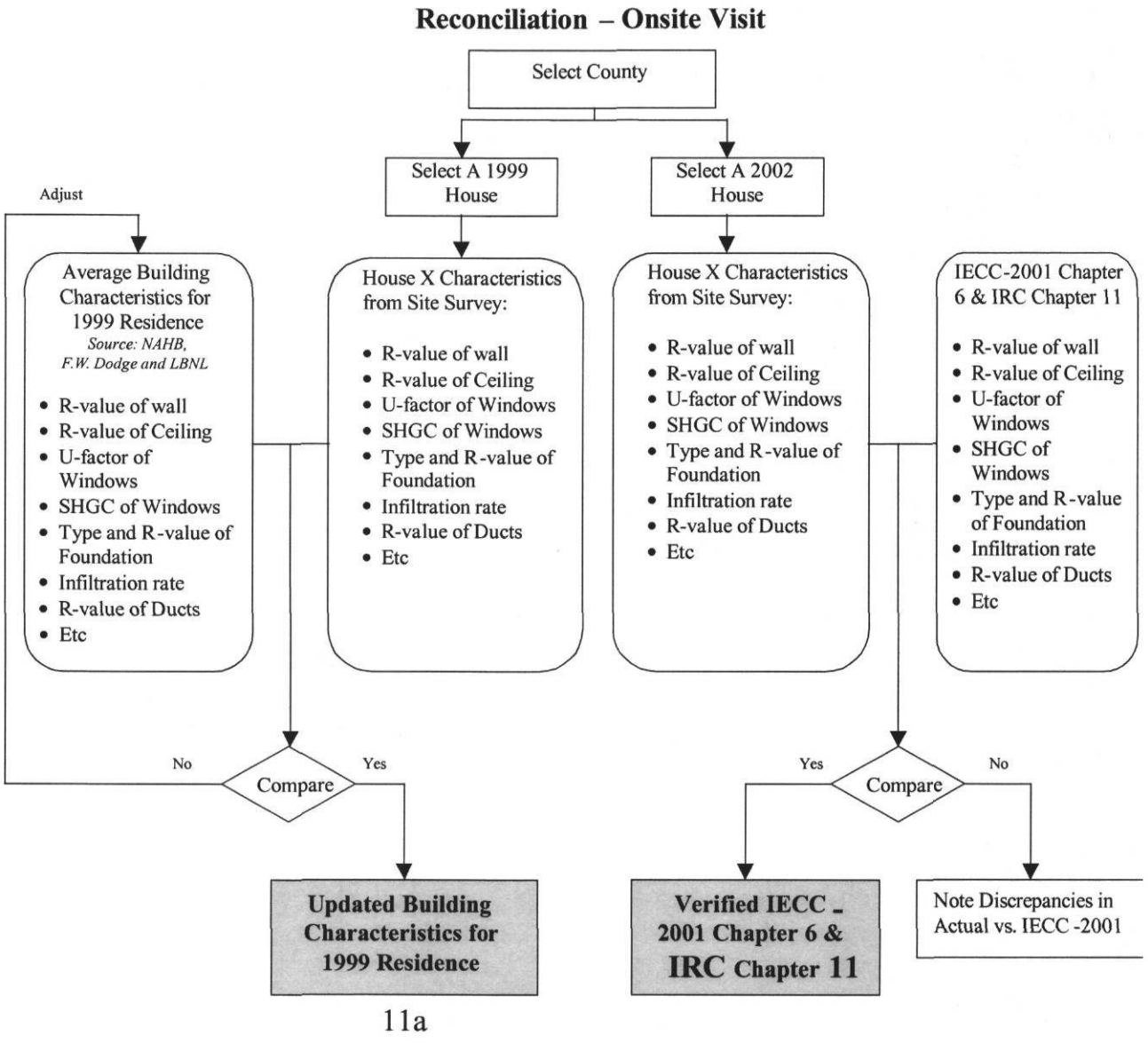

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Figure 11: Reconciliation housing characteristics using on-site surveys.