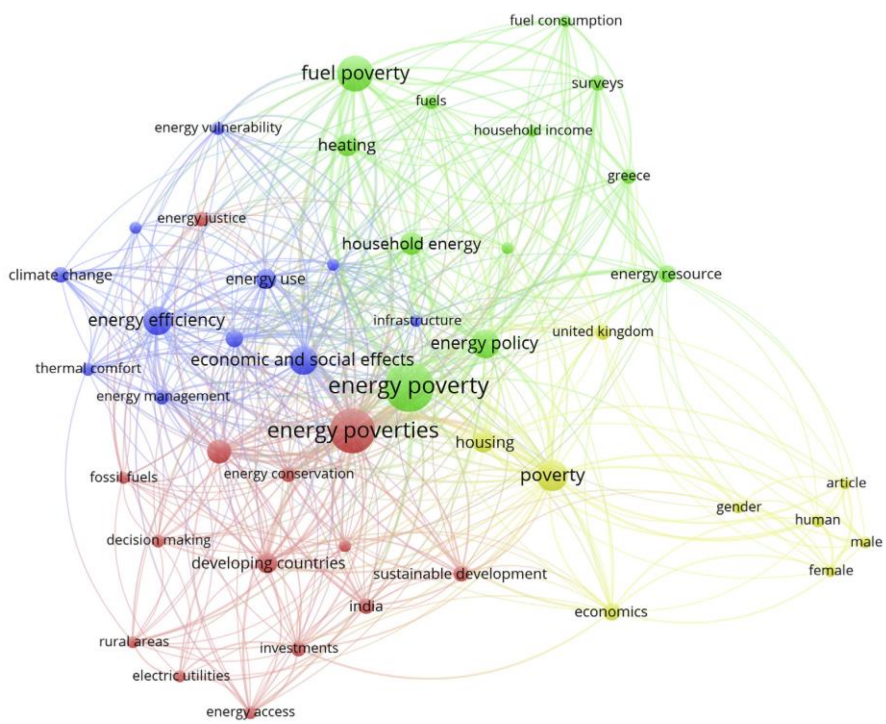
Improving Energy Equity in Calgary: Recommendations for Measuring the Extent and Depth of Energy Poverty

Final Technical Report



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Improving Energy Equity in Calgary: Recommendations for Measuring the Extent and Depth of Energy Poverty

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Image on cover: Primc, Dominko and Slabe-Erker (2021), Figure 10 (most important keywords in energy poverty and fuel poverty research in 2019).

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1 SUMMARY

There is widespread agreement at a conceptual level that energy poverty refers to the inability of a household to maintain adequate energy services, such as heating, within their home. Nonetheless, operational definitions of energy poverty differ in their construction, with important consequences for empirical estimates of the extent of energy poverty in Calgary and for identifying which households are most at risk. This is problematic for policymakers since the accurate measurement of the phenomenon is essential to:

- Indicate the scale of the problem (i.e., how many Calgarians are affected and how severely they are affected?)
- Identify who is affected, what type of home they live in, and where the home is located.
- Inform the design of initiatives and their delivery, and ensure resources and funding are targeting those households most in need.
- Monitor progress, and measure and understand trends (i.e., is the problem getting better or worse over time and why, and are policy interventions working?)

To support the development of The City of Calgary's Energy Equity Strategy, this report aims to: first, identify and critically review the main approaches for measuring energy poverty; second, apply a selection of these approaches to a sample of census geographies in Calgary; and third, recommend an approach for measuring and tracking energy poverty in Calgary.

1.1 Defining energy poverty

The consensus definition of energy poverty is the inability of a household to maintain sufficient levels of essential energy services to have a decent quality of life, such as heating, cooling, lighting, drying, refrigeration, etc. The prevalence and severity of energy poverty in a population is influenced by a range of factors. The primary drivers of energy poverty are low-income, rising energy prices and, in particular, the energy efficiency of the home—building fabrics (e.g., insulation, openings, roof, etc.), heating, cooling and ventilation systems, and appliances. Energy poverty is thus not just a problem of low income, even if low-income households are disproportionately impacted as they tend to live in older, energy inefficient dwellings. For a household to be considered energy poor, it is not sufficient to be low-income or live in an energy inefficient home with high energy bills, but rather both. **Energy poverty is therefore a unique multi-dimensional problem, distinct from income poverty.** Approaches to measuring the prevalence and severity of energy poverty must reflect its multi-dimensional nature. At a minimum, they should account for the energy burden faced by households—i.e., the percentage of household income that goes toward home energy bills.

1.2 Measures of energy poverty

There are three main approaches to measure energy poverty:

① Subjective **self-reporting measures**
Involves collecting and interpreting subjective information from self-assessments (e.g., surveys) by household members regarding whether they see themselves as energy poor. Specifically, whether the respondent feels that they can afford to purchase an adequate level of energy services that satisfy all their heating, cooling, lighting, etc. needs, and whether they feel that they are able to heat or cool their homes adequately.
② Objective **expenditure-based measures**
Involves quantifying energy poverty by considering household income and expenditures on energy services in relation to some pre-defined threshold(s) that delineates energy poor from non-energy poor households.
③ Objective **direct measurements**
Involves the measurement of physical variables (e.g., temperature, humidity, lighting level, etc.) in a home to ascertain the adequacy of energy services, by comparing the recorded values against accepted standards or norms.

Direct measurement approaches are rarely used because of the practical and technical limitations of monitoring energy use in the home—electronic devices ("data loggers") must be installed to record and track data over time.

Self-assessment approaches to measuring energy poverty offer the potential to capture wider aspects of energy poverty beyond income and expenditures, such as social exclusion and material deprivation and the lived experience of being energy poor; this is a key strength relative to the other two approaches. However, the measures of energy poverty generated are subjective and their accuracy will depend on how questions have been interpreted by survey respondents. Furthermore, currently available self-reported indicators relating to energy poverty are largely collected through national-level surveys; these surveys are not designed to provide usable information for community-level measurement within Calgary—the sample sizes are too small. This report thus focuses on expenditure-based approaches commonly used in other jurisdictions and that can be applied at the desired community-level scale in Calgary.

1.2.1 Expenditure-based approaches

The main expenditure-based measures are summarized below.

① 10% ratio indicator

A household is considered energy poor if:

household energy costs > 0.10 x household income

Household income (after tax) can be measured either before or after housing costs, and energy costs can be either actual expenditures or theoretical expenditures to achieve an acceptable level of energy services, like a specific indoor temperature regime (see Section 1.2.2).

Main strengths:

- It is relatively simple to calculate, universally used, and easy to understand and communicate.
- It allows for comparisons across different jurisdictions, providing a standardized benchmark to evaluate the prevalence of energy poverty.
- It is responsive—to different degrees—to the main drivers of energy poverty (i.e., household income, energy prices and energy efficiency).

Main weaknesses:

- While the 10% threshold could be justified by circumstances in the UK in the early 1990s when it was set, it may not be directly extrapolated to other places and times.
- 10% of income was twice what the median household in the UK spent on energy for the home at that time. Double the median expenditure is essentially an arbitrary choice.
- It does not include a cut-off for households with high income, resulting in a large number of false positives (higher income households in large homes can be labelled as energy poor, which does not reflect the definition of an energy poor household).
- It is *highly* sensitive to changes in energy prices (though some degree of price sensitivity is desirable). Changes in energy prices thus dominate changes in the other drivers of energy poverty, diminishing the role of energy efficiency improvements.
- It does not provide a means to directly monetize the severity of energy poverty. Consequently, it incentivizes interventions (policies, programs, projects) that target households on the margins of energy poverty as opposed to those facing the greatest hardship; the indicator can only count whether households move in and out of energy poverty and not whether their financial situation is improved.[1]

[1] It is nonetheless possible to calculate the difference between a household's energy bill and a bill commensurate with 10% of their income (when the former is larger). This difference represents how much an energy poor household's energy bill needs to reduce so it is no longer classified as energy poor. In the UK this calculated value is referred to as the "fuel poverty gap"; in the US it is referred to as the "energy affordability gap". It is worth noting that this measure of energy poverty severity inherits the same strengths and weaknesses of the 10% ratio indicator—e.g., it is highly sensitive to changes in energy prices.

② Double the median share (2M) indicator

A household is considered energy poor if:

household energy costs ÷ household income > 2 x [(median for Calgary) household energy costs ÷ (median for Calgary) household income]

Household income (after-tax) can be measured either before or after housing costs, and energy costs can be either actual or theoretical expenditures (see Section 1.2.2). Note that there are two versions of this indicator: 1. The righthand side of the above equation is dynamic and recalculated annually; and 2. Once calculated using contemporary data, the righthand side of the equation is fixed for a period of time.

Main strengths:

- It is relatively simple to calculate, and easy to understand and communicate. It identifies households who have "unreasonable" energy bills relative to typical (the median) households at that time and location.
- It preserves a focus on the main drivers of energy poverty (i.e., household income, energy prices and energy efficiency).
- When the threshold—right hand side of the above equation—is allowed to vary from year-to-year, it can capture widening inequalities in the efficiency of the housing stock or household incomes, as would be the case if the energy efficiency of some portions of the housing stock improved but others are not.

Main weaknesses:

- It does not include a cut-off for households with high income, resulting in a large number of false positives (households are labelled as energy poor, when they are not).
- When the threshold is allowed to vary from year-to-year, it is overly insensitive to changes in energy prices. This can be viewed as a strength, as it means that the number and composition of who is energy poor is stable year-on-year, making it easier to identify which households should be the focus of interventions. However, the stability of the indicator in its dynamic form is also viewed as a major weakness, as it masks the fact that many households will experience genuine financial hardship in years with high prices.
- It does not directly provide a means to measure the severity of the energy burden experienced by households—i.e., the magnitude of financial hardship experienced by energy poor households in aggregate or on average. Though it is possible to separately calculate a measure of severity (see footnote 1).
- The choice of double the median energy burden of households in Calgary as the threshold is arbitrary and needs to be justified as disproportionate. Though it is consistent with the logic of the original 10% ratio indicator which has been in use for decades.

③ After energy cost poverty (AECP) indicator

A household is considered energy poor if:

equivalized household income < official poverty line for household + equivalized household energy costs

Household income (after tax) is measured after housing costs, energy costs can be either actual or theoretical expenditures, and energy costs and income are adjusted for household size and composition—i.e., equivalized (see Section 1.2.2).

Main strengths:

- It identifies those households most likely to be making tradeoffs between energy consumption and other basic needs, as it captures household already below the official poverty line and those households that are pushed into poverty by having unreasonably high home energy costs.
- It not only provides an estimate of the number of energy poor households but can also provide a measure of the severity (depth) of their energy burdens—i.e., the magnitude of financial hardship experienced by energy poor households in aggregate or on average.

Main weaknesses:

- Nearly all low-income households would be considered energy poor, regardless of their energy costs relative to other households.
- It conflates the issue of energy poverty and income poverty; energy poverty is reduced to a special case of income poverty.
- Policy driven changes in the income distribution will have a larger impact on the number of energy poor households than changes in home energy efficiency and energy costs; local government may prefer an indicator that better reflects changes in home energy efficiency than household incomes, which the municipality may have less influence over.

④ Low-income high cost (LIHC) indicator

A household is considered energy poor if:

equivalized household income < official poverty line for household + equivalized household energy costs

And

Equivalized household energy costs > median household energy costs for Calgary

Household income (after tax) is measured after housing costs, energy costs can be either actual or theoretical expenditures, and energy costs and income are equivalized (see Section 1.2.2).

Main strengths:

- It clearly distinguishes between income poverty and energy poverty and is thus consistent with the accepted definition of energy poverty.
- It significantly reduces false positives (a significant weakness of the 10% ratio indicator).
- It not only provides an estimate of the number of energy poor households but can also provide a measure of the severity (depth) of their energy burdens.

Main weaknesses:

- It is largely insensitive to changes in energy prices, which means it can mask the real hardship rising and high energy prices can present low-income households.
- Setting the energy cost threshold at the median of all households has been criticized, as many households spending up to the median energy costs of the population will face "unreasonable" energy costs and hardship.
- The double relative nature of the indicator—with both the cost and income thresholds being relative measures—results in odd dynamic behaviour, making it difficult to isolate cause and effect over time.
- It is generally viewed by practitioners as overly complex to implement and non-transparent.

⑤ Low-income low energy efficiency (LILEE) indicator

A household is considered energy poor if:

equivalized household income < official poverty line for household + equivalized household energy costs

And

energy efficiency rating of household < target energy efficiency rating for households

Household income (after tax) is measured after housing costs, energy costs can be either actual or theoretical expenditures, and energy costs and income are equivalized (see Section 1.2.2).

Main strengths:

- It clearly distinguishes between income poverty and energy poverty and is thus consistent with the accepted definition of energy poverty.
- It reduces the potential for false positives.
- It places increased emphasis on the energy efficiency of households.
- It not only provides an estimate of the number of energy poor households but can also provide a measure of the severity (depth) of their energy burdens.
- It avoids criticisms resulting from use of the arbitrary median energy cost threshold like with the LIHC indicator (but determining the target energy efficiency rating has its own set of drawbacks—see below).

Main weaknesses:

- Households in energy efficient dwellings above the target threshold value cannot be considered energy poor, regardless of their household income, household size and composition, or energy prices. This runs counter to the consensus definition of energy poverty—where household income, energy prices and the proportion of income needed for adequate energy services are key determinants.
- It neglects the impact of increased energy prices and costs on households with energy efficiency ratings above the target threshold value.
- It is viewed by practitioners as highly complex to implement, including the calculation of the severity of energy poverty. (The energy efficiency rating scale used to calculate the indicator would need to be developed for Calgary.)

⑥ Minimum income standard (MIS) indicator

A household is considered energy poor if:

equivalized household energy costs > equivalized household income – minimum income standard (excluding housing and energy costs)

Household income (after tax) is measured after housing costs, energy costs can be either actual or theoretical expenditures, and energy costs and income are equivalized (see Section 1.2.2).

Main strengths:

- It provides a normative benchmark for assessing energy poverty, defining the minimum income required to meet basic needs after accounting for housing and home energy cost.
- It is closely aligned with the concept of energy equity in terms of capturing the impact of home energy costs on material and social deprivation—i.e., the hardships households face when meeting basic household needs.
- It reduces the potential for false positives and addresses concerns over false negatives (not classifying a household as energy poor when it is).
- It provides a range of measures of the severity of the energy burdens faced by energy poor households—i.e., the total or average magnitude of expenditures on basic living necessities that an energy poor household must forego to first meet their theoretically required energy costs.

Main weaknesses:

- It can focus attention on income standards and basic needs, potentially placing less emphasis on other dimensions of energy poverty, such as energy efficiency. (This concern is addressed by combining the indicator with—for example—the 10% ratio or 2M indicator.)
- A large proportion of low-income households would be considered energy poor, regardless of their energy costs, though to a much lesser extent than with the AECP indicator.
- It is complicated to calculate in the absence of an established, costed basket of goods and services that allows a household to meet their basic needs and achieve a modest standard of living in their specific community (such as the Market Basket Measure).

The above expenditure-based indicators can be combined to address specific shortcomings of individual indicators. For example, either the 10% ratio indicator or 2M indicator can replace the energy cost threshold of the LIHC indicator, which is the subject of much criticism. Similarly, either of the 10% ratio or 2M indicators can be added to either of the AECP or MIS indicators, to form a dual criteria indicator that offers the main strengths of each, while addressing some of their main disadvantages. For example, the MIS indicator will reduce the number of false positives under the 2M indicator alone, while the 2M indicator ensures that lower income households in highly energy efficient dwellings are not counted as energy poor, as they would be with the MIS indicator alone. Furthermore, the inclusion of the 2M indicator ensures more emphasis is given to energy efficiency than it otherwise would be. This dual indicator approach—combining the MIS and 2M indicator—is the recommended approach for Calgary.

1.2.2 Key considerations when estimating expenditure-based indicators

Using actual energy costs in the calculation of energy poverty will fail to capture households that choose to under consume energy to keep their utility bill lower and avoid default of payment—by self-restricting their energy needs. These self-restricting households are often referred to as the "hidden energy poor". Indicators that fail to reflect hidden energy poverty will overlook some of the most vulnerable households in policy design. These concerns are addressed through the use of required (theoretical) energy costs to achieve an adequate level of energy services, as opposed to actual (observed) costs when calculating indicators.

Total household income after-taxes is not an accurate measure of the amount of income that a household has at its disposal to provide an acceptable level of home energy services. Housing costs, like taxes, are often non-discretionary expenditures—especially for low-income households and therefore do not constitute disposable income. The ability of a household to pay for adequate energy services for their dwelling should be assessed on the basis of their after-tax income after housing costs, and not before housing costs.

Definitions of poverty are generally based on equivalized incomes—i.e., incomes adjusted for households of different sizes and composition (combination of adults and children). The purpose of equivalization is to adjust incomes to need; a larger household will need a higher income than a smaller household to have the same standard of living (or economic wellbeing) per occupant. For the same reason, it is argued that household incomes should be adjusted when measuring the prevalence of energy poverty. Failure to do so may greatly overestimate the incomes available to larger households to meet their home energy needs. Depending on the indicator, similar arguments are made to equivalize home energy costs.

1.3 Case study application of indicators in Calgary

Eight of the expenditure-based indicators reviewed, including a dual criteria MIS and 2M indicator, were applied to a sample of 12 Census Dissemination Areas (DAs) across 11 diverse communities in Calgary:

DA 48 06 0091 [**Highland Park**]	DA 48 06 1168 [**Forest Lawn**]
DA 48 06 0312 [**Varsity**]	DA 48 06 1215 [**Ogden**]
DA 48 06 0672 [**Richmond**]	DA 48 06 1636 [**Midnapore**]
DA 48 06 0777 [**Oakridge**]	DA 48 06 1674 [**Castleridge**]
DA 48 06 0956 [**Whitehorn**]	DA 48 06 1793 [**Citadel**]
DA 48 06 1091 [**Castleridge**]	DA 48 06 1880 [**Aspen Woods**]

Building-level data was provided by the City of Calgary for a total of 2,444 dwelling units across the sample of 12 DAs. The median dwelling unit in the sample data had an annual energy bill of $3,298, of which $1,810 and $1,488 was for electricity and natural gas, respectively. This dwelling was 2,178 square feet (ft^2), making annual energy costs per ft^2 equal to $1.51. The building-level energy data was combined with income and shelter cost data from Statistics Canada to construct the energy poverty indicators. The estimated prevalence ("headcount") of energy poor households and, where possible, severity of energy burdens in the 12 DAs are summarized in Table 1 by indicator.

Table 1: Estimated energy poverty headcount and depth by indicator: sample of 12 DAs

10% ratio [income is measured after-tax (AT) and before housing costs (BHC)]	
No. of energy poor households	104
% of total households in sample of 12 DAs	4%
10% ratio [income is measured AT and after housing costs (AHC)]	
No. of energy poor households	275
% of total households in sample of 12 DAs	10%
2M [the energy burden ratio for the median household in the sample of 12 DAs = 6.1% of AT income, BHC]	
No. of energy poor households	445
% of total households in same of DAs	17%
2M [the energy burden ratio for the median household in the sample of 12 DAs = 7.2% of AT income, AHC]	
No. of energy poor households	560
% of total households in same of DAs	21%
AECP [income is measured AT and AHC, and the poverty threshold is defined by the AT low income cut-off (LICO)] *	
No. of energy poor households	525
% of total households in same of DAs	20%
MIS [based on the Market Basket Measure for Calgary, with shelter costs removed] *	
No. of energy poor households	415
% of total households in same of DAs	15%
Energy poverty gap – total	$4,325,060

Energy burden gap – average	$10,420
LIHC [the energy cost threshold is based on the 30 percentile of the sample of 12 DAs and the income-poverty threshold is based on AT-LICO] *	
No. of energy poor households	135
% of total households in same of DAs	5%
Energy poverty gap – total	$33,980
Energy poverty gap – average	$250
LILEE [the income-poverty threshold is based on the MIS* and the energy efficiency threshold is based on the 50 percentile unit energy costs of the sample of 12 DAs]	
No. of energy poor households	355
% of total households in same of DAs	13%
Unit energy poverty gap – total	$181,060
Unit energy poverty gap – average	$510
MIS* and 2M dual criteria indicator [combines the MIS indictor with the 2M after housing costs indicator described above] (this is the recommended approach for Calgary)	
No. of energy poor households	410
% of total households in same of DAs	15%
Energy poverty gap – total	$4,462,650
Energy poverty gap – average	$10,885
Energy bill affordability gap – total	$8,820
Energy bill affordability gap – average	$320

Note: The square brackets show the exact definition of the indicator modelled. The * Indicates that the variables are equivalized. The *energy poverty gap* is equal to the change in home energy bills necessary to remove households from energy poverty. The *unit energy poverty gap* is equal to the change in home energy bills per m^2 of dwelling necessary to remove households from energy poverty. The *energy bill affordability gap* is equal to actual energy bills less affordable energy bills (in this case, bills with an energy burden equal to 7.2% of AT-income, AHC). The total and average energy gaps are on an annual basis.

A set of demographic, dwelling characteristics, and socioeconomic determinants of the likelihood that a households is energy poor were identified from the literature. Data for these determinants was obtained from the 2021 Census of the Population and used to create profiles of households (e.g., the % of households in core housing need, the % of dwellings constructed in 1980 or before, etc.) in each after-tax income group (e.g., <$5,000, $5,000-$9,999, etc.) for each DA in the sample. This information was combined with estimates of the number of energy poor households by income group in each DA to create an aggregate picture of all energy poor households by DA and indicator. For example, energy poor households in Ogden under the dual MIS and 2M indicator exhibit the following characteristics:

- 89% live in dwellings constructed in 1990 or before;
- 76% have only one household maintainer;
- 57% are renters, of which 9% live in subsidized housing;
- 39% are in core housing need;

- 36% live in single-detached dwellings;
- 33% live in apartments with under five storeys; and
- 34% of the primary household maintainers are 65 years or older.

Such an understanding of the characteristics of energy poor households can enhance the design and targeting of interventions (policies, programs and projects) within the most vulnerable communities identified using estimates of extent and depth of energy poverty.

1.4 Recommended approach

First, it should be acknowledged that there is no perfect approach for measuring energy poverty. The choice of approach is about weighing up the relative advantages and disadvantages of different indicators.

Based on a critical review of the main expenditure-based approaches it is **recommended that a dual criteria indicator—combining the MIS and the 2M indicator**—is considered for implementation in Calgary. Energy poverty is a multifaceted issue, and a dual criteria indicator better captures this. As stated above, a dual criteria indicator embodies the main strengths of each individual indicator while addressing key weaknesses of indicators implemented in isolation.

With the recommended indicator, a household in Calgary would be considered energy poor if:

household energy costs ÷ household income > 2 x [(median for Calgary) household energy costs ÷ (median for Calgary) household income]

And

equivalized household energy costs > equivalized household income – equivalized Market Basket Measure for Calgary (excluding the shelter cost component)

Simply put, a household in Calgary is considered energy poor if their disproportionately high energy bill makes it harder to afford a basic standard of living or pushes them into poverty.

To address an important concern with the 2M indicator (i.e., it is overly insensitive to changes in energy prices) not alleviated through the addition of the MIS indicator, the energy burden ratio of the 2M indicator (twice the median share for Calgary), once estimated, should be fixed in the short-term. It should then be reviewed and updated periodically to coincide with updates to the Census of the Population or Calgary's Energy Equity Strategy. When the 2M criterion is allowed to vary year-to-year, it can mask the fact that many households will experience genuine financial hardship in years with high prices, even if the headcount number looks relatively stable.

With the recommended dual criteria indicator, there are several (total or average) measures of the severity of energy poverty that can be calculated, including:

1. The **energy poverty gap** (for all energy poor households). This measures the change in home energy bills *plus* household income necessary to remove households from energy poverty. It is equivalent to the total economic wellbeing forgone by a household from being unable to afford their home energy costs and the costs of basic necessities. With this measure of severity, it is possible to differentiate between: (a) how much of the gap is due to insufficient income; and (b) how much of the gap is due to disproportionate energy bills, or equivalently, the value of other basic living necessities the household must forgo if it first pays its energy bills[2].
2. The **energy bill affordability gap** (for households pushed into energy poverty by paying disproportionate energy bills). This measures the reduction in the household's energy costs necessary to move it out of energy poverty, or equivalently, the basic living expenditures a household must forgo to avoid being energy poor in the absence of interventions to reduce home energy costs.

It is recommended that energy poor households are clustered into "severity bands" based on their estimated *average* energy poverty gap or energy bill affordability gap—e.g., "low gap" through "very high gap". In conjunction with an understanding of the characteristics of energy poor households (demography, housing features and tenure, and socioeconomic status), this can usefully serve to guide policy formulation, targeting and the setting of milestone goals for the Energy Equity Strategy.

While this section provides recommendations for the City of Calgary to consider when formulating its Energy Equity Strategy, the approach(es) adopted by the City may differ as other considerations are taken into account.

[2] Note that (b) is also equivalent to the improvement in economic wellbeing these energy poor households would realize if energy efficiency improvements to their homes reduced energy bills.

2 INTRODUCTION

In general terms, a household is usually considered to be energy poor where they are unable to afford adequate levels of energy services in the home; energy services are functions performed using energy, such as heating, cooling, lighting, refrigeration, drying, etc. (Riva et al., 2021). Nevertheless, whilst there is widespread agreement at a conceptual level that energy poverty refers to an inability to maintain adequate energy services within the home, operational definitions of energy poverty differ decidedly in their construction, with significant consequences for empirical estimates for both the extent of energy poverty and the composition of the energy poor (Legendre and Ricci, 2013; Florian and Sondes, 2019). This is problematic for policymakers since the accurate measurement of energy poverty and the characterization of those most in need is crucial for formulating cost-efficient strategies to address the problem (Eisfeld and Seebauer, 2022). Accurate measurement is essential to (Hills, 2012):

- Indicate the scale of the problem (i.e., how many Calgarians are affected and how severely they are affected?)
- Identify who is affected, what type of home they live in, and where the home is located.
- Inform the design of initiatives and their delivery, and ensure resources and funding are targeting those households most in need.
- Monitor progress, and measure and understand trends (i.e., is the problem getting better or worse over time and why, and are policy interventions working?)

To support the development of The City of Calgary's Energy Equity Strategy for Calgary, this report aims to: first, identify and critically review the main approaches for measuring energy poverty (focusing on the expenditure-based approaches); second, apply a selection of these approaches to a sample of census geographies in Calgary; and third, recommend an approach(es) for measuring and tracking energy poverty in Calgary.

3 DEFINING ENERGY POVERTY

The consensus definition of energy poverty is the inability of a household to maintain sufficient levels of essential energy services to have a decent quality of life, such as heating, cooling, lighting, drying, refrigeration, etc. (Bouzarovski and Petrova, 2015). The issue of energy poverty first emerged on the policy scene in the UK in the 1970s under a different name—fuel poverty—which had a slightly narrower meaning; principally seen as the inability of a household to purchase an adequate level of affordable warmth at a reasonable cost (Bouzarovski, 2014). Rapidly rising energy prices as a consequence of the 1973-74 oil crisis created serious difficulties for households in the UK on fixed, low-incomes, and particularly for those residing in energy inefficient homes that were expensive to keep warm (Lindell et al., 2012). But it was not until Brenda Boardman's book in 1991, also in the UK, that the first operational definition of energy (fuel) poverty was presented (Boardman, 1991): a household was considered energy (fuel) poor if it spent more than 10% of their total household income on all fuel used to heat their homes. This was what the poorest 30% of households were spending on fuel, which was also by chance twice the contemporary median household expenditure. Above this threshold, expenditure on fuel for the heating the home was deemed "disproportionate". A decade later, a nuanced version of Boardman's definition provided the foundation for the definition adopted by the UK's first fuel poverty strategy: energy (fuel) poor households are defined as those *needing* to spend more than 10% of their total household income before housing costs on all fuel used to heat their homes to an *acceptable* level (DETR, 2001). This latter definition is explored further in Section 4.

The prevalence and severity of energy poverty is influenced by a range of factors (consider Figure 1). Most researchers agree that the primary drivers of energy poverty are low-income, high energy prices and, in particular, the thermal and energy efficiency of the home (e.g., insulation, openings, roof, heating, cooling and ventilation systems, and appliances) (Boardman, 2012; Schuessler, 2014). Thus, energy poverty is not just a problem of low-income, even if low-income households are disproportionately impacted as they tend to live in older, energy inefficient dwellings (Riva et al, 2021).

Since vulnerability to energy poverty is a function of household income, and energy efficiency of the home and equipment, it follows that for any given level of income, households have an unequal capability to convert that income into adequate energy services. Furthermore, this is distinct from—and additional to—those deprivations resulting from insufficient income itself. This implies that the overlap between income poverty and energy poverty is less than perfect. For some highly inefficient homes, achieving an acceptable level of energy services may be unattainable at most levels of income. And equally, not all low-income households will experience energy poverty since the latter is also a function of dwelling and equipment efficiency.

When it comes to addressing energy poverty, it is worth recognizing the unique nature of energy services. Energy as a commodity can only be consumed in a piece of equipment (a furnace, water heater, fridge, lightbulb, etc.); the efficiency of this equipment determines the level of services a household receives for a specific level of expenditure on energy bills. Energy poverty is reduced by investing in improving the efficiency of this equipment—a capital expenditure. However, low-income households, by definition, do not have the savings to pay for upgrades. Hence, those investments need to be funded by government or other sources. Notwithstanding the lack of capital, low-income households may also live in rental accommodations and have no authority to improve the energy efficiency of their home. Another consequence of lacking savings is that the only mechanism low-income households have when faced with rising energy prices is to consume less energy, which pushes them into greater hardship. In contrast, a high-income household would likely be incented and be able to invest in energy efficiency capital upgrades.

Addressing general poverty, in contrast, commonly involves increasing incomes—a recurring revenue expenditure. Raising incomes through emergency or seasonal payments can provide a mechanism for short-term relief but does not alleviate the problem longer-term.

In summary, energy poverty is a unique multi-dimensional problem, distinct from income poverty. For a household to be considered energy poor, it is not sufficient to be low-income or live in an energy inefficient home, but rather both. Approaches to measuring the prevalence and severity of energy poverty must reflect its multi-dimensional nature (Belaid, 2018).

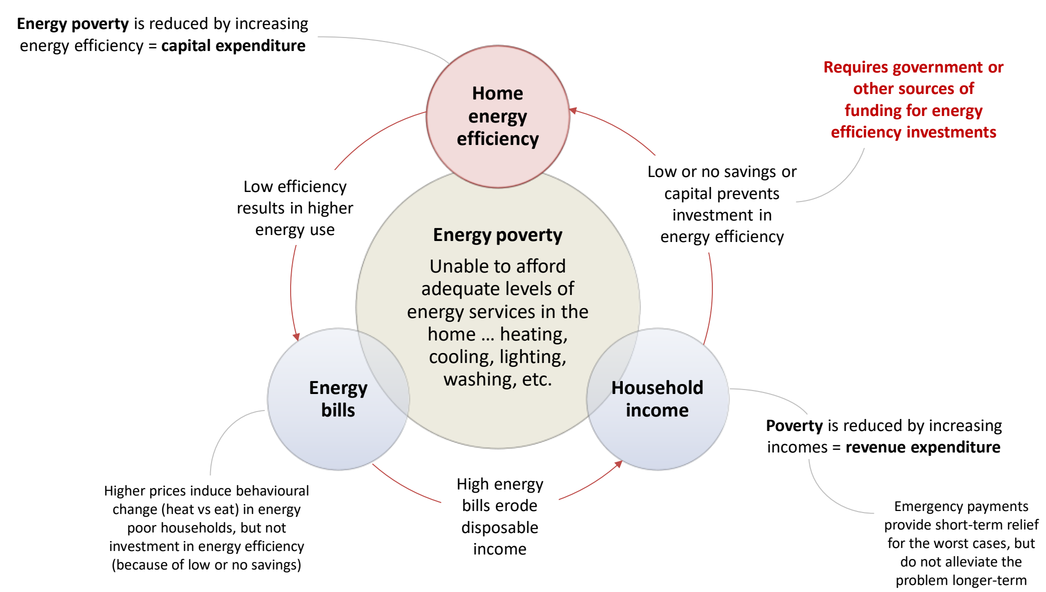


Figure 1: Multi-dimensional problem of energy poverty

4 MEASURES OF ENERGY POVERTY

There are three main approaches to operationalize measurement of energy poverty evident in the literature (Bouzarovski, 2014; Maxim et al., 2016; Thompson et al., 2017; Florian and Sondes, 2019; Riva et al., 2021; EC, 2023; Kez et al., 2024): ① subjective self-reporting measures; ② objective expenditure-based; and ③ objective direct measurements.

Objective direct measurements involve the measurement of physical variables (e.g., temperature, humidity, lighting level, etc.) in a home to determine the adequacy of energy services, by comparing the recorded values against accepted standards. This approach is rarely used because of the practical and technical limitations of monitoring energy use in the home—electronic devices ("data loggers") must be installed to record and track data over time[3] (Primc et al., 2021; Riva et al., 2021). Hence, it is not considered further.

[3] Choosing a suitable standard is also challenging (Kez et al., 2024). In addition, it is necessary to define and collect data from a representative sample of target households in a distinct geographic unit (e.g., neighbourhood) and subsequently generalize the results of the energy poverty

4.1 Self-reporting measures

Self-reported measures of energy poverty refer to various methods of collecting and interpreting subjective information from self-assessments by household members regarding whether they see themselves as energy poor[4]. This typically involves asking a member of the household a series of questions through a survey or interview with an investigator. Respondents are asked, for example (Florian and Sondes, 2019; Riva et al., 2021): Do you suffer from thermal discomfort at home? Does your home suffer from dampness or mold? Do you have difficulty paying your energy bills? Can you afford your energy bills? Are you satisfied with your heating (cooling) equipment? These questions seek to get at whether the respondent feels that they can afford to purchase an adequate level of energy services that satisfy all their heating, cooling, lighting, etc. needs.

The **main strength of this approach to measuring energy poverty is the potential it provides to capture wider aspects of energy poverty** beyond income and expenditures, such as social exclusion, material deprivation, and the lived experience of being energy poor (Healy and Clinch, 2002; Thompson and Snell, 2013). These additional insights provided by self-reported assessments help improve our understanding of the range of drivers behind energy poverty and characterization of vulnerable households, which helps with the formulation and targeting of interventions to ensure no one is left behind (Herrero, 2017). As with most questionnaire-based methods, this approach has its limitations. **Measures of energy poverty generated are subjective and their accuracy will depend on how questions have been interpreted by respondents**. Some researchers have expressed concerns about self-exclusion, where households do not want to identify as experiencing energy poverty if they feel stigmatized, even though they would be classified as such using expenditure-based approaches (Boardman, 2012; Dubois, 2012). Hence, estimates of the prevalence of energy poverty derived from self-assessments need to be interpreted with caution, though they can provide useful insights when combined with objective indicators. Furthermore, self-reported results can be validated against objective measures of related factors, such as arrears on utility bills and the number of disconnections (EC, 2023).

Practically, self-reported indicators relating to energy poverty are nearly exclusively collected through national surveys—e.g., the Canadian Housing Survey, the Canadian Community Health Survey, and the Canadian Social Survey. The results are typically used to assess and contrast energy poverty measurements across countries (or regions within a country) without needing to identify data sources compatible with constructing expenditure-based metrics (e.g., household energy expenditure and income data) (Maxim et al., 2016). Self-reported approaches using national survey results are not a viable option for neighbourhood level measurements of the prevalence of energy poverty within a city like Calgary as the sample sizes would be insufficient at this scale.

assessment to the population of that geographic unit (Dubois, 2012). Ethical concerns arising from the need to enter homes and monitor household behaviour have been identified as a further limitation of this approach (Thompson et al., 2017).

[4] In Europe, approached to measuring energy poverty based on self-reported assessments are also referred to as "consensual" approaches (Thompson et al., 2017; EC, 2023).

4.2 Expenditure-based measures

Expenditure-based measures quantify energy poverty by considering household income and expenditures on energy services in relation to a pre-defined threshold that delineates energy poor from non-energy poor households (EC, 2023; Kez et al., 2024). Expenditures on energy services are a function of energy prices and the energy efficiency of the home and equipment in the home (Schuessler, 2014). There are multiple expenditure-based approaches in the literature and used in practice; in England alone, three different approaches were used to measure energy poverty in less than a decade (Semple et al., 2024). The main expenditure-based measures are presented below. Before looking at these measures, the treatment of energy costs and household income in expenditure-based approaches is first discussed.

4.2.1 Measuring energy costs and income

Several measurement issues are crucial to all expenditure-based indicators—specifically: how income is defined (whether before or after housing costs), whether income is adjusted for household size and composition (a process known as equalization), and whether energy costs reflect actual (observed) expenditures or required (theoretical or modelled) expenditures.

Defining household energy costs and the problem of hidden energy poverty

While actual (observed) energy costs are easier to calculate, it is generally considered a poor measure of energy poverty (Liddell et al., 2012; Moore, 2012). **Using actual energy costs in the determination of energy poverty will fail to capture households that chose to under consume to keep their utility bill manageable and avoid default of payment**—by self-restricting their energy needs. Restricting energy use in the home may blur the lines between being classified as energy poor or not (Legendre and Ricci, 2018). For instance, accepting colder room temperatures to save costs may mean that a household does not reach the 10% expenditure-income threshold (see Section 4.2.2) to be classified as energy poor, though their lived experience suggests otherwise. Ample survey evidence shows that low-income households underspend, often substantially, on energy at the expense of living in cold homes (DETR, 2000; Anderson et al., 2010; Brunner et al., 2012; Chard and Walker, 2016). Hirsch et al. (2011) found that, on average, UK households consumed only two thirds of their theoretical energy needs, with low-income households most likely to be self-restricting energy use. Self-restricting households—who consume less energy than expected with reference to an adequate level of energy services—are often referred to as the **hidden energy poor** (Eisfeld and Seebauer, 2022). Indicators that fail to reflect hidden energy poverty will overlook some of the most vulnerable households in policy design and risk the misallocation of resources.

The use of the theoretically required energy expenditure addresses these concerns by capturing the extent to which households may economize (under-consume) on energy use in the home to meet the costs of other basic necessities, creating a more holistic indicator of energy poverty (Cong et al., 2022). The official definition of the 10% ratio indicator adopted by the 2001 UK fuel poverty strategy, for example, is based upon the energy costs *theoretically required* to maintain adequate warmth rather than *actual* energy expenditure. **Hidden energy poverty is thus reflected in the indicator through the use of theoretical energy costs**. Indeed, the indicator is not intended to measure whether households are in fact spending more than 10% of their income on energy for the home, but rather whether they would *need* to do so to achieve an acceptable level of energy services in their dwelling on the basis of observed income data and modelled energy consumption relating to thermal and energy efficiency of the dwelling and equipment (Legendre and Ricci, 2015).

While measuring the prevalence of energy poverty on the basis of theoretical energy costs is preferred, it is not without problems in addition to the practical difficulties associated with such a data intensive exercise. Indeed, several academics argue that the use of a "one-size-fits-all" approach to modelling household energy requirements and costs is problematic. For example, failure to account for cultural differences in households and their use of rooms was found to lead to inaccurate estimates of theoretical energy consumption (Todd and Steele, 2006). Furthermore, there is evidence that households with individuals with disabilities or pre-existing conditions can have higher home energy needs as a result of having to keep rooms warmer for longer periods of time, needing to use specific energy intensive equipment, or requiring additional washing and drying capabilities (Snell et al., 2015). These latter omissions will likely lead to an underestimation of energy needs and costs of particularly vulnerable households.

The indicator is based on a calculation of annual theoretical energy costs relative to annual household income. However, in practice, the ratio of energy costs to income will typically be higher in winter months than summer months. Meeting the excess energy costs during the winter may be genuinely more difficult for poorer households. Hence, a case could be made for calculating the ratio on the basis of theoretical energy costs for a typical winter month against monthly household income. As the climate changes, and cooling demand in summer months increases, this could be revisited.

Defining household income: before or after housing costs

Total household income is an imperfect measure of the adequacy of income to provide an acceptable level of home energy services (Moore, 2012). The case for excluding housing costs from AT-income when measuring energy poverty is strong (Hills, 2011). Like taxes, housing costs are often non-discretionary expenditures—especially for low-income households—and therefore do not constitute disposable income. A household cannot spend their mortgage or rent payments on energy services any more than they can spend provincial or federal taxes on home energy bills. The ability of a household to pay for adequate energy services for their particular dwelling is dependent on their AT-income after housing costs (AHC), and not before housing costs (BHC) (Moore, 2012). Furthermore, housing costs are highly variable across neighbourhoods in a city and across time. So, estimating the prevalence of energy poverty using AT-incomes BHC is likely to provide a misleading picture of the spatial distribution of energy poor households across a city.

Accounting for household size and composition

Whether AT-income is measured BHC or AHC, there remains a question over whether to adjust the income metric for households of different sizes and composition. Definitions of poverty are generally based on equivalized incomes. As explained in Box 1, the **purpose of equivalization is to adjust incomes to need**; a larger household will need a higher AT-income than a smaller household to have the same (per capita) standard of living, though the difference in household incomes is not directly proportional to the difference in household size. Some argue that household incomes should be adjusted when measuring the prevalence of energy poverty (Legendre and Ricci, 2015; Florian and Sondes, 2019; DESNZ, 2023). Failure to equivalize AT-household incomes will result in underestimation of energy affordability issues for larger households since—on the basis of a fixed income threshold approach to measuring energy poverty—estimation of larger households' non-energy household needs will be proportionately greater. Put another way, failure to equivalize AT-incomes may greatly overestimate the incomes available to larger households to meet these adequate home energy needs. Evidence suggests that equivalization has a substantial effect on the socio-demographic composition of the energy poor (GLA, 2008; Fahmy et al., 2011). As a result, it will have important implications for the design of strategies to effectively target initiatives at households most vulnerable to energy poverty.

It is sometimes argued that if incomes are equivalized then estimated energy costs should likewise be adjusted for household size and composition. The amount of energy needed to secure an adequate level of energy services will depend on the number of individuals in a household, as well as the specific needs of those individuals (e.g., whether they are older or very young, have disabilities, or are chronically ill, etc.). To account for this effect, several of the alternative expenditure-based indicators discussed below equivalize energy costs (e.g., the low-income, high-cost indictor). However, given that the purpose of equivalization is to adjust AT-income to need, this argument is questionable when using theoretical energy costs (Moore, 2012). In this case, estimated energy costs are, in effect, already equivalized to the extent that the modelling of costs accounts for variations in household size and composition, as well as other dwelling characteristics. Practically, even if theoretical energy costs are fully equivalized, these costs comprise a relatively small component of actual total household spending, so that the overall effect of energy cost equivalization should, in any case, be modest compared to the effects of equivalizing AT-incomes (Moore, 2012). Regardless, when using a ratio-based definition like the 10% indicator (see Section 4.2.2), making the same adjustment for household size and composition to both sides of the fraction would simply cancel out and make no difference to the calculation (Hills, 2011). This is thus only a potential issue when using non-ratio-based indicators.

Box 1: Equivalization—accounting for households of different sizes

Households come in different sizes and compositions. This is problematic when assessing the level of household income needed to support a standard of living. Assuming that the benefits derived from household income are always divided equally between household members, then it follows that that for the same level of household income, members of smaller households are better off than members of larger ones. But is it realistic to assume that someone in a household that is half the size enjoys twice the standard of living?

Consider the example of person A living alone with an income of $100,000. Now, assume their partner, who has no income, moves in. On a per-capita basis, the income available to support a standard of living is effectively halved, now $50,000. Considering some expenditures, like food and clothing, it is probably true to expect that some expenses will double, such that the economic wellbeing of person A is effectively cut in half. Other types of expenditures, however, are not likely to double or change at all. For example, rent or mortgage payments, a large household expense, are mostly fixed and will not tend to increase proportionally with increases in household size.

This example illustrates that when household size increases, expenses are expected to increase to maintain the same standard of living for each household member, but not necessarily at the same rate as the increase in household members. This reflects "economies-of-scale" associated with larger households. By simply dividing total household income by the number of household members, these economies-of-scale are ignored. As a result, the standard of living experienced by individuals in larger households is underestimated. A preferred approach to measuring standards of living involves weighting household members beyond the first by less than 1. Clearly, household expenses will increase with each additional member, but the amount that they increase by should not become larger with each additional member, since each additional members cost less than previous ones because of economies-of-scale.

The rule for determining the rate at which the denominator in the calculation of per-capita income measure rises is referred to as an equivalence scale—the adjusted incomes are made "equivalent" between individuals living in households of different sizes. The resulting measure of income is referred to as equivalent income. There are multiple equivalence scales in use in literature; a computationally simple equivalence scale uses the square root of household size.

Source: Based on Skuterud, Frenette and Poon (2004)

4.2.2 The 10% ratio indicator

As noted in Section 3, the 10% ratio was the first indicator to measure energy poverty. According to the indicator as originally specified, a household is considered energy poor if it has to spend more than 10% of their total household income before housing costs on all energy theoretically required to heat their homes to an acceptable level. The definition has subsequently been broadened to include a satisfactory level of *all* energy services. With the 10% ratio indicator, a household h in geography i at time t is energy poor if:

$$\frac{\bar{E}_{h,i,t}}{I_{h,i,t}} > 0.10 = \bar{E}_{h,i,t} > 0.10 \times I_{h,i,t}$$

Where $\bar{E}$ is the *theoretical* energy costs to achieve an adequate level of energy services and I is household after-tax (AT) income before housing costs (BHC). And:

$$\bar{E}_{h,i,t} = \sum_{j=1}^{J} \bar{f}_{j,h,i,t} \times p_{j,i,t}$$

Where $\bar{f}$ is the *theoretical* quantity of fuel source j to provide an acceptable level of energy services and p is the price of that fuel. In the application to Calgary in Section 5, only two fuels are considered: electricity ($j = 1$) and natural gas ($j = 2$).

The **main advantage of this indicator is that it is relatively simple to calculate, and easy to understand and communicate** (Romero et al., 2018; Aguilar et al., 2019). As a result, the indicator is used in multiple jurisdictions. This makes it easy to draw comparisons across different jurisdictions, providing a standardized benchmark to evaluate the prevalence of energy poverty.

Variations of the income metric in the 10% ratio indicator

On the basis of the discussion in Section 4.2.1, the 10% ratio indicator could[5] be reformulated such that a household h in geography i at time t is energy poor if:

$$\frac{\bar{E}_{h,i,t}}{\bar{\bar{I}}_{h,i,t}} > 0.10 = \bar{E}_{h,i,t} > 0.10 \times \bar{\bar{I}}_{h,i,t}$$

Where $\bar{E}$ is theoretical energy costs as defined above and $\bar{\bar{I}}$ is equivalized household AT-income after housing costs (AHC). And:

$$\bar{\bar{I}}_{h,i,t} = \bar{I}_{h,i,t} \times \frac{1}{\epsilon_h}$$

$$\bar{I}_{h,i,t} = \left(I_{h,i,t} - HC_{h,i,t}\right)$$

Where $\bar{I}$ is the household AT-income *after* housing costs, I is the household AT-income *before* housing costs, HC are the non-energy housing costs (depending on whether the household is an owner or renter, these include mortgage/rent payments, property taxes/condominium fees, water and other municipal services), and ϵ is an appropriate equivalization factor for household h.

The equivalization factor used by Statistics Canada when calculating the levels of disposable income needed for families of different sizes in different regions of Canada to maintain a modest, basic standard of living as defined by the Market Basket Measure (MBM) (Canada's official poverty line) is based on the square root of household size. The MBM defines poverty thresholds based on the cost of a basket of goods and services (food, clothing, shelter, transportation, and other necessities) for a reference family of four[6]. A family with a disposable income below the region-specific MBM threshold is considered to be

[5] As the income measure is household specific and is not being compared with a population measure of income or income-poverty, the equivalization of AT-income AHC is optional (Heindl, 2014); hence, the use of "could" as opposed to "should" here.

[6] The reference family of four comprises one male and one female adult aged 25 to 49 with two children (a female child aged 9 and a male child aged 13).

living in poverty. To adjust disposable income for families that differ in size to the reference family, Statistics Canada uses the following equivalization factor (for further details see Danieles et a., 2024):

$$\epsilon_h = \frac{\sqrt{S_r}}{\sqrt{S_h}}$$

Where S_h is size of family h and S_r is the size of the reference family. In the context of the MBM where the reference family size is four (i.e., $\sqrt{S_r} = 2$), E is equal to 2.00 if $S_h = 1$, 1.41 if $S_h = 2$, 1.16 if $S_h = 3$, 1 (unchanged) if $S_h = 4$, 0.89 if $S_h = 5$, and so on. Accordingly, the calculation of equivalized household AT-income after housing costs (AHC), $\bar{\bar{I}}$, for the 10% ratio indicator is calculated as:

$$\bar{\bar{I}}_{h,i,t} = \bar{I}_{h,i,t} \times \frac{\sqrt{S_h}}{\sqrt{S_r}}$$

If energy costs are also to be equivalized, the same equivalization factor used for incomes should not be used, as the relationship between household size and energy costs is not the same as with household size and general living costs (Antepara et al., 2020). If the number of occupants in a household increases by one person in an identical living space, heating demand would increase very little compared to the increase in the cost of living. The impact of occupancy on energy costs has been observed to be less than the impact of occupancy (Imbert et al., 2016). In recognition of this observation, the equivalization factor used for energy costs in the current UK definition of energy poverty is different to that used for household income; the equivalization factor for energy costs is driven more by the size of usable floor area of dwellings than occupancy (DESNZ, 2023).

It should be noted that the above definitional choices (using AHC, equivalization of incomes) will influence who is identified as vulnerable and thus who should be the focus of policy interventions. For instance, including housing costs introduces a bias towards households that own their own home outright—which leads to the question of who are these households in Calgary? Failing to equivalize incomes will introduce a bias towards single households—again, who are these households in Calgary? Excluding housing costs and failing to equivalize incomes will introduce bias against low-income households with children, who are renting or paying a mortgage.

Criticisms of the 10% ratio indicator

There are five main concerns with the 10% ratio indicator:

First, when created, the 10% threshold represented both (a) the average expenditure on energy by the poorest 30% of households at that time and (b) twice the contemporary median share of home energy expenditures for all households. The latter rationale for the threshold, which defines a relative level of energy expenditure, was considered the most relevant and served to consolidate support for the indicator (Lindell et al., 2012; Schuessler, 2014; Romero et al., 2018). However, in practice, it has been implemented as an absolute measure, not varying with changes in income levels or energy efficiency improvements over time (Boardman, 2012). **While the 10% threshold was relevant to circumstances in the UK in the early 1990s, it may not be directly extrapolated to other places and times**.

Put another way, **use of the 10% threshold in other jurisdictions seems to be a rather arbitrary choice**. What the 10% ratio indicator shows is the "tail" of the distribution of home energy costs in relation to income. As a result, the number of households identified as energy poor depends greatly on whether the threshold is set at the tail end or intersects a thicker part of the distribution. This choice will impact both the number and type of energy poor households—and in turn policy design. Nonetheless, one cannot avoid the need to make an arbitrary judgement when it comes to setting a threshold (Hills, 2011). These concerns led to proposals for the 2M ("twice the average spend") indicator discussed below.

Second, the 10% ratio indicator provides a poor indicator of the affordability of energy services—especially for households with high incomes (Hills, 2011). Basically, when used to measure the prevalence of energy poverty, **the 10% ratio indicator does not include a cut-off for households with high income**. This leads to a higher numbers of households with high incomes being identified as energy poor, when the reality is their high energy costs are proportional to their high incomes (Florian and Sondes, 2019). Put another way, **a large number of false positives are captured** by the indicator (i.e., households are labelled as energy poor, when they are not). The following example from Moore (2012) illustrates this nicely: "*31% of single-person households* [in the UK] *who have fuel costs of between 13% and 14% of residual income AHC are in the lowest income decile* [poorest 10% of households], *having an average income of £5,276 and average fuel costs of £709. However, a further 23% of such households are in the third income decile or above with average incomes AHC of £11,154 and fuel costs of £1,499. With well over twice the average residual income of the first group, this group is likely to have significantly less difficulty in meeting their fuel costs, despite being classed as equally fuel poor*." As Moore (2012) notes, such anomalies will be observed in all definitions of energy poverty that are based on the ratio of energy costs to household income irrespective of how income is defined. This seems incongruous with the definition of energy poverty provided in Section 3.

Third, **the 10% ratio indicator, with its fixed threshold, is highly sensitive to changes in energy prices**—potentially underestimating the scale of the problem when prices are low and overestimating it when prices are high (Hills, 2011; Moore, 2012; Boardman, 2012; Romero et al., 2018; Aguilar et al., 2019). Empirical evidence from the UK for the period 1996-2010 shows that changes in the headcount of energy poor households over this period are dominated by changes in energy prices, relative to changes in home energy efficiency or household incomes. As energy prices change from year-to-year, the distribution of household energy costs shifts in relation to the fixed threshold, which can result in sharp changes in the number of energy poor households. This can **mask the impact of policies that improve housing energy efficiency** (or that improve income levels), which can lead to conclusions that such policies are ineffective when they are in fact quite effective (Boardman, 2012).

Nonetheless, while Moore (2012) and Boardman (2012) acknowledge that the 10% ratio indicator is very sensitive to changes in energy prices, they and others (e.g., Fahmy, 2011; Schuessler, 2014) note that indicators should equally not mask the impact of rising prices on the affordability of home energy services. All expenditure-based indicators characterize energy poverty as a problem of excess expenditure on energy, where expenditure is the product of energy use in the home (influenced by its energy efficiency) multiplied by corresponding prices. At least conceptually, there is thus nothing wrong with an energy poverty indicator that is responsive to energy prices. Other things being equal, it is reasonable to expect that rising energy prices will increase the number of energy poor households. Indeed, having an indicator that is sensitive to changes in the affordability of home energy services due to price increases would seem central to the reason for having energy poverty indicators. Hence, we **should not automatically discard price-sensitive indicators of energy poverty**, but rather decide to what extent the indicator should be responsive to changes in energy prices.

Fourth, related to the previous shortcoming, **the 10% ratio indicator provides an incentive to focus policy on reducing energy bills rather than on increasing incomes** (Hills, 2012; Moore, 2012). This may not be a concern for local governments but kept in mind. The use of a ratio indicator with home energy costs as the numerator and household income as the denominator means that a $10 reduction in energy bills for households close to the 10% threshold would have the same effect as a $100 increase in income. Equally, to avoid going into energy poverty, the same household would require a $100 increase in income for each $10 increase in home energy costs[7].

Fifth, **the 10% ratio indicator does not directly capture the depth of energy poverty** faced by households, alongside the number of energy poor households. The headcount of energy poor households will include both those that are marginally above the 10% threshold and those that are well above it (i.e., the most severely energy poor households). In terms of social equity, it may be more desirable to focus interventions (policies, programs, projects) on households with the highest energy cost burdens, facing the greatest hardship. In other words, those households with the deepest energy poverty. However, with the 10% ratio indicator or any indicator that only measures headcounts, local government may receive no credit for doing so, unless interventions improve the affordability of home energy services sufficiently to push households across the threshold. The indicator only counts households on either side of the threshold. Consequently, an intervention designed to improve energy efficiency of dwellings for the most severely energy poor households can appear mis-targeted as it may not have any discernible impact on the headline number of energy poor households (Hills, 2011). Indeed, **there is a perverse incentive to focus interventions on those households on the margins of energy poverty, rather than those with greatest hardship**.

[7] Moore (2012) provides a numerical example that further illustrates the greater emphasis placed on changes to energy bills: Consider a household with an annual income of £10,500 and total energy costs of £1,000 (the energy cost ratio is thus 9.5%). Now, assume that in the following year the household's energy costs increased by £200 to £1,200 while household income increased by $1,000 to £11,500. Despite the large increase in income the household would now be defined as energy poor, with an energy cost ratio of 10.4%. The reality is, however, that the increase in income of £1,000 is more than adequate to compensate for the £200 increase in energy costs, leaving the household better-off by £800.

The "capped" 10% ratio indicator

To reduce the risk of "false positives", Schuessler (2014) suggests including an additional rule to exclude high income households from consideration. This so-called "capped 10% ratio" indicator would specify an income cut-off above which a household is very unlikely to experience energy poverty. The cut-off should initially be set generously, erring on the side of overestimation rather than underestimation, and calibrated to ensure particularly vulnerable households are not excluded. It could start at the official poverty line, for example.

As originally proposed by Schuessler (2014)—based on the European Union's official threshold for relative poverty (set at 60% of the median equivalized AT-income AHC), with the **capped 10% ratio indicator**, household h in geography i at time t is energy poor if:

$$\frac{\bar{E}_{h,i,t}}{\bar{I}_{h,i,t}} > 0.10 = \bar{E}_{h,i,t} > 0.10 \times \bar{I}_{h,i,t}$$

And (both conditions must hold):

$$\bar{\bar{I}}_{h,i,t} < 0.60 \times \bar{\bar{I}}_{m,t}$$

Where $\bar{E}_h$ is theoretical energy costs, $\bar{I}_h$ is the household AT-income AHC of household h, $\bar{\bar{I}}_h$ is the equivalized household AT-income AHC of household h, and $\bar{\bar{I}}_m$ is the median equivalized AT-income AHC across all households. The righthand side of the above equation can be replaced with the Market Basket Measure (Canada's official poverty line); now, household h in geography i at time t is energy poor if:

$$\frac{\bar{E}_{h,i,t}}{\bar{I}_{h,i,t}} > 0.10 = \bar{E}_{h,i,t} > 0.10 \times \bar{I}_{h,i,t}$$

And:

$$\bar{\bar{I}}_{h,i,t} < MBM_{YYC,t}$$

Where MBM is the equivalized Market Basket Measure for Calgary (YYC) at time t adjusted for the size of household h. To use the MBM poverty line in this way, the household income (after-tax, after housing costs) measure would require further adjustments to align with the definition of "disposable income" used by Statistics Canada. Broadly speaking, **this variation of the 10% ratio indicator identifies households that are both income poor and energy poor**.

Capping the 10% ratio indicator to address the risk of false positives is a simple fix that is easy to communicate. The **addition of an income constraint to the 10% ratio indicators as part of a two-part metric is in line with the official definition currently in use in Scotland** (ONS, 2023).

4.2.3 The 2M indicator

While the 10% ratio indicator was intended to be relative to both the energy costs and income of the median household, in practice it has been constant at 10% over time. This means that in any given year for which the indicator is estimated whether a household is considered energy poor or not is dependent on its energy costs and income compared with the median household in the UK in the early 1990s, as opposed to being relative to the circumstances of contemporary households at the location of interest. An alternative ratio-based approach initially proposed by the European Commission (EC, 2010) defined a household as energy poor if its home energy costs are greater than double the mean energy bill relative to average income across all households[8]. That is, household h in geography i at time t is energy poor if:

$$\frac{E_{h,i,t}}{\bar{I}_{h,i,t}} > 2 \times \frac{E_{m,t}}{\bar{I}_{m,t}}$$

As originally specified by the European Commission, E and $\bar{I}$ are, respectively, the *actual* energy costs and the (non-equivalized) AT-income AHC of household h, E_m are the median or mean *actual* energy costs across all household, and $\bar{I}_m$ is the median or mean after-tax (AT) income AHC across all households. Notwithstanding concerns about using actual energy costs and non-equivalized income, **the consensus among researchers is that it is better to use the median value rather than the mean value** (Hills, 2011; Moore, 2012). The main reason is that the mean value is more sensitive to extreme values or "outliers". Schuessler (2014) also provides the following moral argument in favour of the median: Home energy costs or the share of income spent on energy services are typically skewed right, and as a result, the median will precede the mean. Hence, using the median value is more favourable to households that might be energy poor.

There are two versions of the 2M indicator: 1. Where the righthand side of the above equation is dynamic and recalculated annually; and 2. Where the righthand side of the equation is fixed for a period of time at the calculated percentage using contemporary data.

As a relative measure, **the dynamic version of the 2M indicator is insensitive to changes in energy prices**. When energy prices rise for all households, the entire distribution of household energy costs will shift to the right. Those households that started out below (or that started out above) the median household are likely still below (or still above) the median after the price increase. The composition of energy poor households is thus fairly stable from year-to-year, making it easier to identify households that should be the focus of interventions. Furthermore, due to its relative nature, **the dynamic version of the 2M indicator is able capture widening inequalities in the efficiency of the housing stock** or incomes. If the energy efficiency of only a small segment of the housing improved, but other segments did not change, this poverty would be reflected in the indicator's headcount (Hills, 2011). However, as noted above, an indicator that is insensitive to changes in energy prices is not universally viewed as an advantage. Indeed,

[8] This belongs to a family of so-called "2M indicators": double the mean household expenditure on energy; double the median household expenditure on energy; double the mean share of household expenditure on energy; and double the median share household expenditure on energy (Heindl, 2013).

during a period of high energy prices in the UK, Moore (2012) notes that the indicator showed little change in the number of energy poor households, despite the fact that many households experienced genuine difficulty in meeting their energy needs. Rising energy costs are reflected in the increasing median share of income required to meet energy needs for all households, but not the number of households in relative energy poverty. As a result, **the indicator masks the hardship experienced by vulnerable households during periods of high energy prices**. Moore (2012) goes further, arguing that while dynamic relative indicators are appropriate for measuring income poverty (as annual changes in income levels are relatively modest over time), they are "*much more questionable*" for measuring energy poverty given the typical year-on-year volatility of energy prices.

The 2M indicator (both the dynamic and fixed version) also **suffers from many of the same disadvantages as the 10% ratio indicator**:

- It lacks an income cut-off and thus can classify some higher income households as energy poor.
- It is limited to measuring the number of energy poor households and cannot by itself capture the depth of energy poverty.
- It provides an incentive to focus policy on reducing energy bills rather than on increasing incomes, as reductions in energy bills will have a greater impact on the headcount of energy poor than increases in income of the same magnitude. Though this may be less of a concern for local governments who will have greater influence over home energy efficiency than incomes.

Furthermore, **the choice of double the median share of energy expenditure relative to income as a normative threshold seems arbitrary**; why not two and a half or one and a half times? Also, why should a high-income household that spends more than twice the median share of all households be considered energy poor? Heindl and Schuessler (2015) also find that the 2M indicator has some "awkward" dynamic properties. In short, it **can cause a reduction in the energy poverty headcount in the face of decreasing incomes or increasing energy prices--the opposite of what would be expected** (see Box 2).

The shortcomings of a dynamic 2M indicator are addressed by fixing the threshold—calculated using local contemporary data—for a period of time. The fixed version of the 2M indicator also shares two key advantages of the 10% ratio indicator:

- It is relatively simple to calculate, and easy to understand and communicate. It identifies households who have "unreasonable" energy bills relative to typical (the median) households at that time and location.
- It preserves a focus on the main drivers of energy poverty (i.e., household income, energy prices and energy efficiency).

Box 2: Dynamic properties of the 2M indicator for energy poverty

As explained on page 8 of Heindl and Schuessler (2015): Shifting a statistical distribution to the right by a positive constant, c, shifts the distribution's median, M, by the same amount to M + c. This is also true for the shifted double median value, 2M + c, but not for the new double median. The new double median is 2 x (M + c), which is thus c further to the right than the old double median. Hence, less of the distribution's probability mass is in the tail beyond the new double median than was beyond the original double median. If the distribution in question is one of energy expenditure shares and the double median share is a threshold for energy poverty, it follows that fewer households are now energy poor than before. Yet the addition of a constant reflects an increase in energy expenditures for all households. For a uniform distribution of incomes, this amounts to a lump-sum increase in energy expenditures for all. For other income distributions, the rise in expenditure will be positive for all, but not equal in size. Irrespective of the income distribution, the 2M indicator suggests that a rise in energy expenditure for all, which does not affect the relative position of households or the shape of the expenditure share distribution, will lead to a reduction in energy poverty, other things being equal. The number of households above the new double median threshold will decrease. This is obviously nonsensical. Rising energy costs (or shrinking incomes) for all should not result in lower measured levels of energy poverty given that the relative positions of all households remain the same. This violates Amartya Sen's widely accepted axiom for measures of poverty; less money for a poor household will increase poverty, and not the other way around as implied by the 2M indicator.

Source: Heindl and Schuessler (2015)

4.2.4 The after-energy cost poverty (AECP) indicator

A shortcoming of the 10% ratio indicator is that it does not include a cut-off for high income households. As a result, some households classified as energy poor will have sufficiently large incomes to be able to absorb higher home energy costs, while not having to make trade-offs with other essential expenditures. To address this shortcoming, an alternative way to measure the prevalence of energy poverty is to look at whether a household's AT-income AHC falls below a certain threshold after deducting home energy costs. These households are classified as "after-energy costs poor". **The choice of threshold is essentially a normative judgement but basing it on the official poverty line is easiest to justify**. The original definition of the after-energy cost poverty (AECP) indicator proposed by Hills (2011) used the UK's official poverty line at the time[9], setting the threshold as: 60% of the median household AT-income AHC plus the theoretical household energy costs. Furthermore, both income and energy costs were equivalized for household size and composition. Hence, with the AECP indicator, household h in geography i at time t is energy poor if:

$$\bar{\bar{I}}_{h,i,t} < 0.60 \times \bar{\bar{I}}_{m,t} + \bar{\bar{E}}_{h,i,t}$$

Where $\bar{\bar{E}}$ is the equivalized theoretical energy costs and $\bar{\bar{I}}$ is the equivalized household AT-income AHC of household h, and $\bar{\bar{I}}_m$ is the median equivalized AT-income AHC across all households (all as defined above). The righthand side of the equation defines the income-poverty threshold for the indicator. Note that as a household's theoretical energy costs varies from one household to another, the income-poverty threshold line will also vary depending on whether home energy costs are relatively low or high compared to the median household; this is illustrated in Figure 2. Looking at Figure 2, households B, C and D are considered energy poor because they are essentially left with a residual income below the official poverty line if they spend their theoretical energy costs.

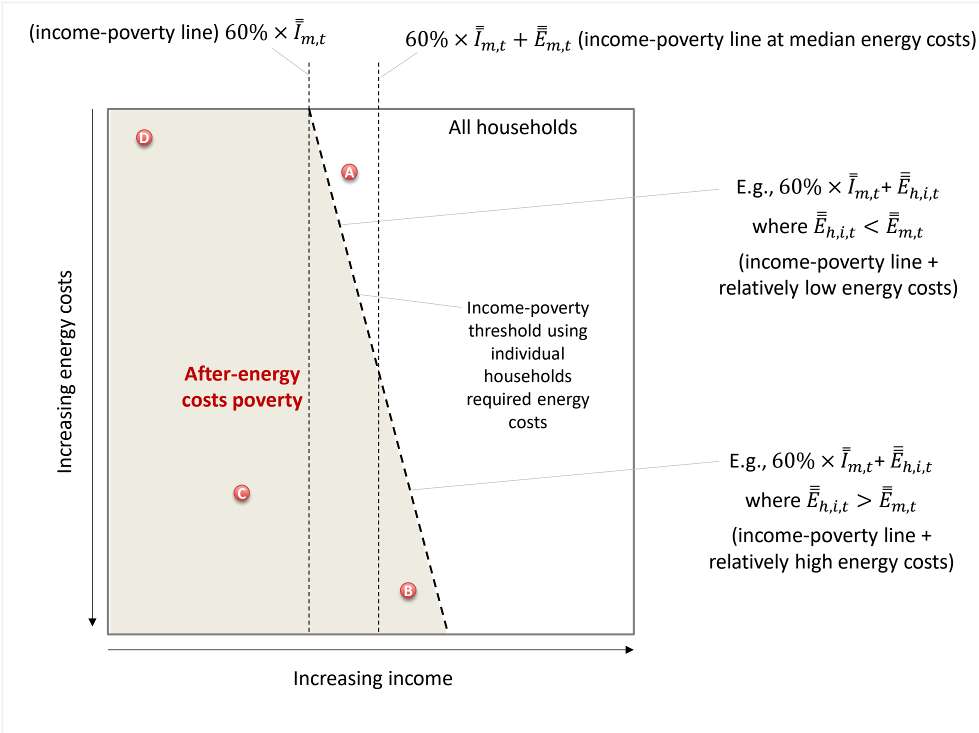
[9] This is also the European Union's standard for relative poverty; 60% of the national median equivalized AT-income AHC.

As mentioned above, the official poverty line in Canada is defined by the Market Basket Measure (MBM). The MBM could be used as a basis for specifying the income-poverty threshold for application of the AECP indicator to measure energy poverty in Calgary. However, **as the MBM is based on the costs a household incurs to purchase a specific basket of goods and services to meet their basic needs and achieve a modest standard of living in Calgary, using it as a basis for setting the income-poverty threshold would essentially transform the AECP indicator to a Minimum Income Standard (MIS) indicator**, which is discussed in Section 4.2.7.

In addition to providing an estimate of the number of energy poor households, the AECP indicator can also provide a measure of the severity (depth) of their energy burdens—i.e., the magnitude of financial hardship experienced by energy poor households, in aggregate across all energy poor households or as an average per household.

As originally specified, one advantage of the AECP indicator is that income is defined after housing costs (Florian and Sondes, 2019; Charlier and Legendre, 2019; Aguilar et al, 2019). However, the main advantage of the AECP indicator is that it correctly identifies households that are currently in poverty, and in particular, those that are pushed into poverty by the costs of meeting their theoretical energy services (household C in Figure 2). That is, it **usefully identifies those households on the margins of energy poverty who are pushed into poverty by having unreasonably high home energy costs relative to what a typical household is needing to spend**. This is central to concerns about energy poverty (Hills, 2011). It also excludes households just above the poverty line with relatively low home energy costs (household A in Figure 2). However, the majority of households below the poverty line before incorporating the costs of theoretical energy services would be classified as energy poor with the AECP indicator (households C and D in Figure 2). The fact that a **large proportion of low-income households would be considered energy poor, regardless of their energy costs, is a major drawback** with the indicator (Aguilar et al., 2019; Florian and Sondes, 2019). For example, a household like D in Figure 2, whose income is significantly below the poverty threshold, would be classified as energy poor with the AECP indicator even though their dwelling is close to net-zero. Legendre and Ricci (2015) argue that this can create confusion between income poverty and energy poverty, even though it is generally accepted they are distinct problems (Hills, 2012; Boardman, 2012). It seems more appropriate to view household D as income poor, rather than energy poor. To target households most in need, Moore et al. (2018) suggests using a lower income-poverty threshold, such as 50% of the median household AT-income AHC as opposed to 60%. They also argue that the **income-poverty threshold provides a poor measure of whether a household can actually afford their energy costs, as it fails to reflect the local costs of meeting other basic household needs**, other than housing costs.

Figure 2: Illustrating the after-energy costs poverty indicator



Source: Adapted from Hills (2011)

When applied to UK data over the period 1996-2010, the headcount of energy poor households calculated using the ACEP indicator was found to be relatively stable; this contrasts with the highly variable headcount observed under the 10% ratio indicator. In further contrast to the 10% ratio indicator, changes in income were found to be the dominant determinant of changes in the headcount, as opposed to changes in energy bills. **Interventions that result in changes to the income distribution will have a larger impact on the number of energy poor households than interventions that change home energy costs**. The 10% ratio indicator and 2M indicator, in contrast, incentivize policymakers to design incentives that focus on reducing energy bills rather than on increasing incomes. Local governments may want to choose an indicator more focused on policy outcomes they have more influence over, to facilitate accurate monitoring and evaluation of the impact of interventions they implement.

4.2.5 The low-income, high-cost indicator

To clearly delineate between income poverty and energy poverty, Hills (2011) supplemented the AECP indicator with the addition of a second threshold to capture households that have both low-incomes and live in energy inefficient dwellings. In contrast to the indicators outlined above, this aligns better with how the issue of energy poverty is commonly framed—i.e., as overlap between inefficient dwellings and poverty. The purpose of the additional constraint is to identify households experiencing "unreasonable costs" to achieve an adequate level of energy services. The energy cost threshold proposed by Hills (2011) is based on the median theoretical energy costs of all households. Theoretical energy costs are adjusted for household size and composition.

With the low-income, high cost (LIHC) indicator as originally defined by Hills (2011), household h in geography i at time t is energy poor if:

$$\bar{\bar{I}}_{h,i,t} < 0.60 \times \bar{\bar{I}}_{m,t} + \bar{\bar{E}}_{h,i,t} \text{ [the AECP indicator]}$$ [10]

And

$$\bar{\bar{E}}_{h,i,t} > \bar{\bar{E}}_{m,t}$$

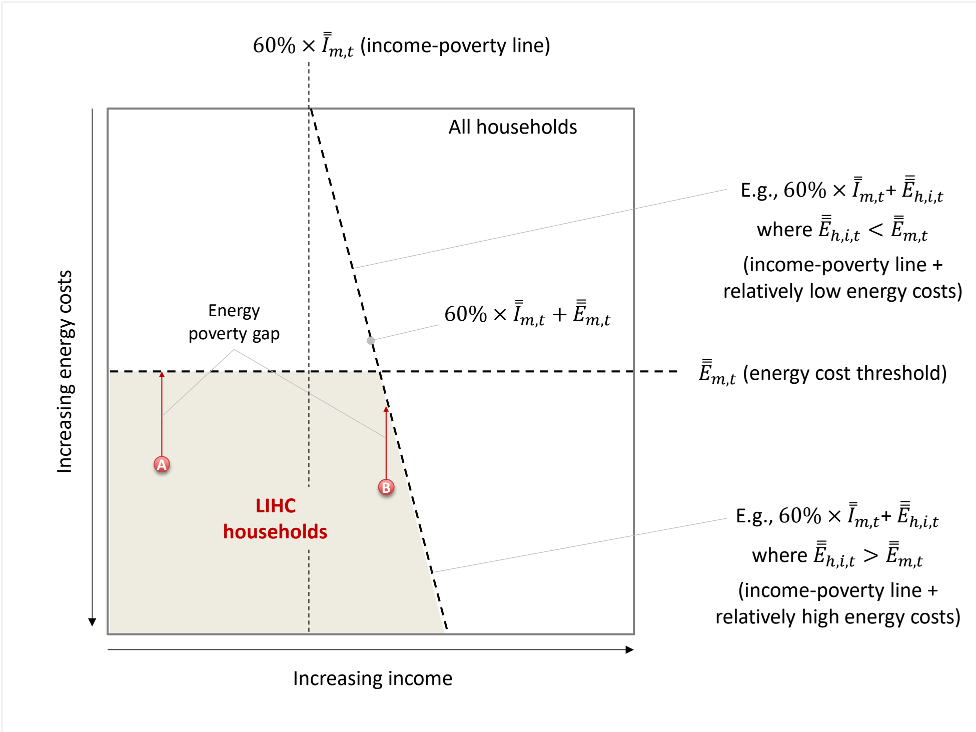
Where $\bar{\bar{E}}$ is the equivalized theoretical energy costs of household h or the median household m,and $\bar{\bar{I}}$ is the equivalized AT-income AHC of household h or the median household m. Note that the first threshold is simply the AECP indicator. All notation is as defined above. The effect of combining both thresholds is illustrated in Figure 3. As shown, households A and B who are after-energy cost poor (to the left of the income-poverty threshold) and have theoretical home energy costs above the median cost for all households (above the energy cost threshold[11]) are classified as energy poor. Household B, while just above the official poverty, is pulled into after-energy cost poverty because of its high energy costs.

The **main strength of the LIHC indicator is it clearly distinguishes between income poverty and energy poverty** and is thus consistent with the accepted definition of energy poverty (Legendre and Ricci, 2015; Charlier and Legendre, 2019). This addresses a shortcoming of the AECP indicator, which conflates the two issues. With the AECP indicator a large proportion of low-income households would be considered energy poor, regardless of their home energy requirements; this will not happen with the LIHC indicator due to the imposition of the energy cost threshold. A shortcoming of the 10% ratio indicator is also addressed through the inclusion of a cut-off for high-income households; though this is also the case with the AECP indicator.

[10] For application in Calgary, the righthand side of this income-poverty threshold would need to be replaced with Canada's official poverty threshold.

[11] Note the y-axis is in reverse order; below the line is actually above the cost threshold.

Figure 3: Illustrating the low-income, high cost (LIHC) indicator



Source: Adapted from Hills (2011)

A **second major advantage of the LIHC indicator is it provides a measure of the severity (or "depth") of the problem**—the magnitude of financial hardship experienced by energy poor households in aggregate or on average—in addition to measuring the prevalence of energy poverty. The depth of energy poverty is measured through a separate indicator, the "energy poverty gap"[12]. For a low-income household facing unreasonable home energy costs (household A in Figure 3), the energy poverty gap is given by the difference between its theoretical energy costs and the energy cost threshold. For a household at the margins of poverty that would fall below the poverty line if it were to spend its theoretical energy costs (household B in Figure 3), the energy poverty gap is given by the reduction in home energy costs necessary to put the household above the income-poverty threshold. These energy poverty gaps can be summed across all energy poor households to provide a measure of the financial scale of the problem in Calgary or an area of Calgary.

An important benefit of the energy poverty gap metric is that **it captures the impact of interventions that reduce theoretical energy costs for energy poor households, even if those households do not move above the energy cost threshold**. Some households will be classified as energy poor not because of high energy use and bills, but rather because of very low incomes. In these cases, removing households from energy poverty is not a function of home energy efficiency improvements alone; it will also require bill assistance

[12] Strictly speaking, this is officially referred to as the "fuel poverty gap" in the UK.

and other measures to improve incomes. For these households, the desired outcome of interventions to improve home energy efficiency is thus not to eliminate energy poverty, but rather to reduce energy burdens. For example, reducing energy costs as a proportion of income from 22% to 12% for household A may be more important (result in greater improvements in wellbeing) than reducing energy costs of household B from 12% to 9% of their income. This is despite the fact that the improvements would take household B out of energy poverty under the 10% ratio indicator, but household A would remain classified as energy poor. **An indicator that provides a measure of the depth of energy poverty enables policymakers to design interventions and set targets that emphasize reductions in energy burdens and improvements in affordability and wellbeing through energy efficiency investments, rather than solely reductions in the number of energy poor household** (since no matter how much energy efficiency improvements achieve some, households will remain energy poor).

The energy poverty gap, EPG, for household h in geography i at time t is generalized as:

$$EPG_{h,i,t} = \left(\bar{\bar{E}}_{h,i,t} - \bar{\bar{E}}_{m,t}\right) - max\left\{\left[\bar{\bar{I}}_{h,i,t} - \left(\left(0.60 \times \bar{\bar{I}}_{m,t}\right) + \bar{\bar{E}}_{m,t}\right)\right], 0\right\}$$

All notation is defined above.

The LIHC headcount indicator is less sensitive to changes in energy prices compared with the 10% ratio indicator. Hills (2011) argues that this is a positive outcome as the consistency this provides should help policymakers be more confident that ongoing interventions will continue to target the correct group of households. Even if the headcount component of the LIHC indicator is relatively stable when energy prices change, the impacts of rising (or falling) energy prices are captured through increases (or decreases) in the energy poverty gap metric. However, as explained above and emphasized by Moore (2012), price insensitivity in an indicator is not necessarily a good thing; it can mask the hardship escalating energy prices can present low-income households and fail to adequately reflect the achievements of interventions designed to reduce energy costs through home energy efficiency improvements. Hirsch et al. (2011) likewise see little value in an indicator that barely changes over time in the presence of significant changes in energy prices or energy efficiency.

The income-poverty threshold proposed by Hills (2011) is generally accepted in the literature, though as noted above, Moore et al. (2018) argues it does not accurately determine whether a household can actually afford their energy bill. The proposed **energy cost threshold based on the median of all households has been roundly criticised** in the literature (Boardman, 2012). Setting the energy cost threshold at the median for all households is essentially arbitrary without normative justification and implies that expenditure on theoretical energy services up to the median should be considered "reasonable" for low-income households. Yet, **requiring low-income households to spend up to the median already overburdens them** (Schuessler, 2014). Hence, setting the energy cost threshold at the median will result in too few households being classified as energy poor, despite having "unreasonable" energy costs. As Boardman (2012) notes, "*if you only have 60% of the average income* [the basis for the income-poverty threshold], *at most you should be expected to pay 60% of the average fuel bill*." Moore (2012) also recommends that the energy cost threshold is set "*significantly below the median*" to capture low-income households with lower theoretical energy costs, who nevertheless live in very energy inefficient dwellings and would benefit from interventions that addressed these inefficiencies.

It is worth noting, however, that in simulations using German data, Heindl and Schuessler (2015) found that setting the energy cost threshold of the LIHC indicator at the median expenditure of the poorest 30% of households produced some odd dynamic behaviour; the LIHC indicator with the revised energy cost threshold proved unresponsive to increased income inequality even though the affordability of energy services for low-income households decreased significantly. This is a consequence of the relative nature of the indicator. Indeed, **the double relative nature of the LIHC indicator**—a quotient of two separate relative metrics—**is viewed as a weakness**. **In addition to producing odd dynamic behaviour, it makes it difficult to isolate cause and effect over time** (Romero et al., 2018). Not only is the LIHC indicator non-responsive to increased income inequality, but it also fails to capture an economy-wide increase in energy expenditures due to its reliance on a "floating median", with its need to always keep 50% of households below the energy cost threshold (Heindl and Schuessler, 2015). This makes it very difficult to eradicate energy poverty through interventions to reduce energy costs in low-income, high-cost dwellings (Moore, 2012; Thompson et al, 2017). The relative nature of the LIHC indicator also **makes it difficult to set policy goals based on eliminating energy poverty** (Hirsch et al., 2011). Furthermore, the only way to capture the impact of changing energy prices is through secondary analysis of changes in the energy poverty gap, which makes the indicator more challenging to understand and communicate.

Alternative energy cost thresholds

To address concerns over the dynamic behavior of the LIHC indicator—how affordability changes over time as a result of changes in the underlying variables—Heindl and Schuessler (2015) suggested replacing the current energy cost threshold (i.e., requiring energy costs to exceed the median for all households) with an alternative threshold requiring households to spend at least x% of their AT-income AHC on theoretical energy services. The most obvious alternative criterion is the 10% ratio indicator. The modified LIHC indicator, LIHC-10%, would now classify household h in geography i at time t is energy poor if:

$$\bar{\bar{\bar{I}}}_{h,i,t} < 0.60 \times \bar{\bar{\bar{I}}}_{m,t} + \bar{\bar{\bar{E}}}_{h,i,t} \text{ [the AECP indicator]}$$[13]

And

$$\frac{\bar{\bar{E}}_{h,i,t}}{\bar{I}_{h,i,t}} > 0.10 = \bar{\bar{E}}_{h,i,t} > 0.10 \times \bar{I}_{h,i,t}$$

Broadly speaking, **this variation of the LIHC indicator identifies households that are relatively poor and have relatively high energy bills**.

[13] For application in Calgary, the righthand side of this income-poverty threshold would need to be replaced with Canada's official poverty threshold.

Unsurprisingly as it is from the same researchers, this looks a lot like the capped 10% ratio indicator proposed by Schuessler (2014) (recall Section 4.2.2). Based on simulations with German data, Heindl and Schuessler (2015) found this LIHC-10% to be more restrictive than the LIHC indicator, resulting in a lower energy poor headcount. But importantly, it was found to have desirable dynamic properties, in contrast to the LIHC indicator. The LIHC-10% indicator behaves as expected in terms of changes in estimated energy poor headcounts in response to increases in energy costs, decreases in income, and increasing inequality.

Finally, it is generally accepted by practitioners and policymakers that **the LIHC indicator is overly complex to implement and because of the complexities involved in its calculation, also not very transparent** (Moore, 2012; Romero et al., 2018; Aguilar et al., 2019).

4.2.6 The low-income, low energy efficiency indicator

The UK Government adopted the LIHC as the official measure of energy poverty in the 2015 Fuel Poverty Strategy. Following consultation in 2019, an updated measure of energy poverty—the low-income, low energy efficiency (LILEE) indicator—was introduced in England for the 2021 Fuel Poverty Strategy. This remains the official measure of energy poverty in England. According to the LILEE indicator, a household is considered energy poor if they reside in a dwelling with a Fuel Poverty Energy Efficiency Rating (FPEER) of band D or below and their residual AT-income AHC after deducting theoretical energy costs falls below the official poverty line[14]. The latter condition is the AECP indicator, which is also used as the income-poverty threshold in the LIHC indicator. The difference between the LIHC indicator and the LILEE indicator is the replacement of the energy cost threshold with an energy efficiency threshold.

With the LILEE indicator, household h in geography i at time t is energy poor if:

$$\bar{\bar{I}}_{h,i,t} < 0.60 \times \bar{\bar{I}}_{m,t} + \bar{\bar{E}}_{h,i,t} \text{[the AECP indicator]}$$[15]

And

$$FPEER_{h,i,t} = [D, E, F, G]$$

[14] The FPEER is based on the UK Government's Standard Assessment Procedure (SAP) for assessing the energy performance of domestic dwellings. Similar to SAP, the FPEER methodology generates an energy efficiency rating from 0 (lowest) to 100 (highest). This rating is then transformed into an energy efficiency "band" from G (lowest) to A (highest). For a household to be considered energy poor, their dwelling must have a FPEER of D or below. Further details of the FPEER can be found in the Fuel Poverty Energy Efficiency Rating Methodology Handbook (DECC, 2014).

[15] For application in Calgary, the righthand side of this income-poverty threshold would need to be replaced with Canada's official poverty threshold.

Where bands D, E, F, and G correspond to FPEERs of 55-68, 39-54, 21-38 and 1-20[16], respectively, and all other notation is as defined above.

While the LIHC indicator is intended to address the main shortcomings of the 10% ratio[17] and AECP[18] indicators, the LILEE indicator is designed to overcome key concerns with the LIHC indicator—mainly relating to its double relative character and the use of an energy cost threshold based on the median of all households. Indeed, the strength of **the LILEE indicator is it avoids the problems listed above associated with using the median expenditure threshold** by replacing it with an energy efficiency threshold. Placing **increased emphasis on energy efficiency is also viewed as a strength** of the LILEE indicator. As such, the LILEE indicator is reasonable for tracking the roll-out of energy efficiency upgrades in low-income households. Furthermore, the **LILEE indicator still provides a means of measuring the severity of energy poverty** (the energy poverty gap) in addition to providing a headcount measure. In the case of the LILEE indicator, the energy poverty gap, EPG, for household h in geography i at time t is generalized as (DESNZ, 2023):

$$EPG_{h,i,t} = \left(\bar{\bar{E}}_{h,i,t}^{F(h)} - \bar{\bar{E}}_{t}^{F(C)}\right) - max\left\{\left[\bar{\bar{I}}_{h,i,t} - \left(\left(0.60 \times \bar{\bar{I}}_{m,t}\right) + \bar{\bar{E}}_{t}^{F(C)}\right)\right], 0\right\}$$

Where: $\bar{\bar{E}}^{F(h)}$ is the equivalized theoretical energy costs of household h at its current FPEER and $\bar{\bar{E}}^{F(C)}$ is the equivalized theoretical energy costs of that household at band C of the FPEER (the energy efficiency threshold). All other notation is defined above. With the LILEE indicator, the energy poverty gap is expressed unequivalized:

$$uEPG_{h,i,t} = EPG_{h,i,t} \times \epsilon$$

Where: $uEPG_h$ is the unequivalized energy poverty gap for household h and ϵ is an appropriate equivalization factor for household h.

However, use of an energy efficiency threshold is not without its problems, notwithstanding concerns about how well an energy efficiency rating serves as a reasonable proxy for costs. First**, households in energy efficient dwellings** below the FPEER threshold[19] (bands A-C) **cannot**, by definition of the indicator, **be considered energy poor, regardless of their household income, household size and composition, or energy prices** (Semple et al., 2024). For example, someone living in an energy efficient dwelling but struggling to afford their energy bills due to a very low-income would not be identified as energy poor; they would simply be identified as income poor. This runs counter to the consensus definition of fuel poverty—that household income, energy prices and the proportion of income needed for adequate

[16] A FPEER of 1 represents a very inefficient dwellings (homes with high energy costs) and a FPEER of 100 represents a very efficient dwellings (zero energy costs) (DESNZ, 2023).

[17] For example, it has a cut-off for high income households.

[18] For example, it excludes a large number of low income households with low home energy requirements and costs.

[19] Recall, lower ratings are better, corresponding to more energy efficient homes.

energy services are key determinants (Boardman, 2008). A second major criticism of the LILEE indicator is that it effectively **neglects the impact of increased energy prices and costs on households in bands A-C dwellings** (Middlemiss, 2017). Moreover, the FPEER has relatively low sensitivity to energy prices across all bands (Croon et al., 2023; Semple et al., 2024).

To address some of these concerns, Moore et al. (2018) and Florian and Sondes (2019) have proposed replacing the energy efficiency rating with an alternative normalized expenditure metric that directly reflects the theoretical energy costs of the household in their home. They recommend using unit energy costs per unit of floor space as the basis for creating a normalized (1-100) rating scale, where 100 indicates very low unit energy costs (and implied high energy efficiency). Not only will this mitigate concerns about the low energy price sensitivity of the LILEE indicator, but it also addresses biases introduced through the use of total energy cost metrics. This means that poorer ratings are not biased towards dwellings with larger floor areas, unlike the LIHC indicator, which is based on total energy costs. This bias towards larger properties results in some of the poorest households, least able to afford their energy costs, who reside in below average sized energy inefficient dwellings not being identified as energy poor. In contrast, high income households with adequate energy budgets who live in larger more energy efficient dwellings are classified as energy poor. This anomaly can be avoided by using a normalized expenditure scale based on theoretical energy costs per unit floor space and setting a threshold on this scale to delineate low unit cost dwellings (with high implied efficiency) from high unit cost dwellings (with low implied efficiency).

4.2.7 The minimum income standard indicator

An alternative measure of energy poverty proposed by Moore (2012) is based on a "reference budget standard" or "minimum income standard" (MIS) approach. A minimum income standard—as the term implies—is the minimum income needed by different households in specific locations to enjoy an acceptable, pre-determined basic standard of living (Bradshaw et a., 2008). Being income poor (relative to others) provides a good starting point for identifying those households most in need. However, it is generally accepted that poverty is not the same as low-income. Conceptually, definitions of poverty have moved beyond income alone and other capitals[20], towards a multi-dimensional definition based on a range of material and social deprivations—i.e., social norms about what people need and should not go without. This wider conceptualization of poverty is closely linked with energy poverty; if a dwelling is difficult to heat or cool, that may decrease the scope of what occupants can do within their home, it may limit their available budget for other things, or it may undermine their general health in turn restricting what they can do and who they can be. **Measuring energy poverty based on a minimum income standard approach seems like a far more justifiable approach than considering income alone.** Moore et al. (2018) argue that because the LIHC and LILEE indicators do not include a minimum living costs component

[20] Income is only one resource which households can draw upon to meet their needs. Households may also have access to other forms of financial capital (e.g., savings), human capital (e.g., knowledge that enhances their resilience), and social capital (e.g., friends or relatives what can provide help).

(informed by a MIS), they are unable alone to determine whether a household's theoretical energy costs are affordable.

In the context of measuring energy poverty, a household would be classified as energy poor if it had insufficient AT-income to pay for its theoretical energy costs, after paying for housing costs and other minimum living costs (as defined by an MIS). Formally, with the MIS indicator, household h in geography i at time t is energy poor if:

$$\bar{\bar{E}}_{h,i,t} > \bar{\bar{I}}_{h,i,t} - MIS_{i,t} \times (1-\alpha)$$

Where: $\bar{\bar{E}}$ is the equivalized theoretical energy costs and $\bar{\bar{I}}$ is equivalized household AT-income after housing costs (AHC) of household h and MIS is the minimum income standard for geography i, and α is the fraction (%) of MIS comprising shelter costs (i.e., energy costs and housing costs) (Moore et al., 2018). To avoid double counting it is necessary to remove shelter costs which are already captured in separate, often more precise, estimates of $\bar{\bar{E}}$ and $\bar{\bar{I}}$. (The City of Calgary has detailed household level estimates of $\bar{\bar{E}}$ available for the purpose of calculating indicators.) Through the multiplication of $(1-\alpha)$, MIS is reduced to the costs of food, clothing and footwear, transportation, and other necessities. The objective of the MIS indicator is to calculate whether a household's residual budget for spending on energy needs (i.e., their AT-income AHC less other essential living costs) is greater or less than their theoretical energy costs. **Any household whose AT-income is insufficient to cover their theoretical energy costs and housing costs, plus other basic living costs** (as defined by the MIS) **should be considered "low-income" for the purposes of measuring energy poverty** (Moore et al., 2018).

As mentioned above, the official poverty line in Canada is defined by the Market Basket Measure (MBM). According to the MBM, a household is considered to be below the poverty line if it has insufficient disposable income to purchase a specific basket of goods and services (specified qualities and quantities of food, clothing, shelter, transportation and other necessities) that allows them to meet their basic needs and achieve a modest standard of living in their community. As this measure is based on having or not having enough disposable income to purchase a fixed basket of goods and services, it is an absolute measure of poverty (Government of Canada, 2018). The MBM is essentially an MIS and can be used as a basis for the MIS indicator. In this case, a household h in geography i at time t is energy poor if:

$$\bar{\bar{E}}_{h,i,t} > \bar{\bar{I}}_{h,i,t} - MBM_{YYC,t} \times (1-\alpha)$$

Where: MBM_{YYC} is the MBM threshold for Calgary (YYC) (equivalized for household h). In 2023, MBM_{YYC} was estimated $57,909 (current dollars); this represents the costs of the basket of goods and services for a reference family of two adults and two children. The square root of household size is the equivalence scale used to adjust the MBM threshold for other household sizes (recall the presentation in Section 4.2.2). In 2023, α for Calgary is 39% and $(1-\alpha)$ is 61%:

Component	Current dollars	% of total	Cumulative % of total

Food	$15,002	25.9	25.9
Clothing	$1,894	3.3	29.2
Transportation	$5,119	8.9	38.1
Other expenses	$13,289	22.9	61.0
Shelter	$22,604	39.0	100.0
Total	$57,909		

Source: Table 11-10-0066-01, Statistics Canada

The **MIS indicator is considered the most accurate and meaningful expenditure-based approach for measuring energy poverty, because it evaluates the problem from its core economic roots. Consideration of the disposable income available to a household to meet its energy needs, after basic living costs have been met, is a justifiable way to measure energy poverty** (Moore, 2012; Romero et al., 2018; Barella et al., 2022). Despite the conceptual merits of the approach, a lack of, or technical difficulties associated with determining a reference "minimum income standard" has severely limited its application in other jurisdictions. The availability of the MBM for 66 different regions and locations in Canada, nevertheless, enables the application of the MIS indicator approach in Calgary.

Hirsch et al. (2016) argue that the threshold for the MIS indicator should be lowered to be reasonably confident when stating that "*anyone below this income line is likely to have a much greater risk of deprivation than anyone above it*". For example, the MBM for Calgary in 2023 is $57,909 per year. A more conservative approach would set the threshold at 90% ($52,118) or even 80% ($46,327) of that amount. (The percentage reduction in the MBM is somewhat arbitrary and would need to be justified.) In this case, a household is considered energy poor if:

$$\bar{\bar{I}}_{h,i,t} - \bar{\bar{E}}_{h,i,t} > 0.9 \times \left(MBM_{YYC,t} \times (1 - \alpha)\right)$$

Indeed, the Scottish Government adopted this more conservative approach for the *Tackling Fuel Poverty in Scotland: A Strategic Approach*, using a residual income threshold of 90% of the full MIS. Reflecting the additional costs of living for households where individuals have disabilities or long-term chronic illnesses, the Strategy also included significant "mark-ups" of the MIS, by increasing the equivalence factors.

With the MIS indicator, **it is still possible to measure the depth of energy poverty.** In this case, the energy poverty gap (a measure of depth) is given by the magnitude of expenditures on basic living necessities that an energy poor household must forego to first meet their theoretical energy costs (Hills, 2011). Furthermore, the depth of energy poverty can be presented on a sliding scale of "severity bands", with energy poor households clustered according to the extent to which basic living costs need to be reduced to afford theoretical energy bills—e.g., the number and percentage of all energy poor households who must reduce expenditures on basic living costs by (say) up to 10%, 10-20%, 20-30% and so on. These intervals could be labelled as (say) "low energy poverty gaps", "moderate energy poverty gap", "high energy poverty gap", and so on. Presenting the energy poverty gap on a scale can serve to guide policy. For example:

- If the goal of government is to reduce the overall prevalence of energy poverty, then it could target interventions at the group of energy poor households with the largest share of total energy poor households; conversely
- If the goal of government is to improve the affordability of basic energy needs for the most severely impacted and vulnerable households, then it could target interventions at those households falling into the "very high energy poverty gap" interval.

Combining the MIS with other indicators

In practice, **the MIS indicator has been used in combination with the 10% ratio indicator**; essentially to address a key shortcoming of the latter, whereby too many high-income households are classified as energy poor. This dual criteria approach was implemented by the Scottish Government. Their rationale for doing so was twofold (Scottish Fuel Poverty Definition Review Panel, 2017):

1. The issue of energy poverty is multifaceted, and a dual criteria definition would better capture this; and
2. There was strong support that energy costs should feature centrally in any definition of energy poverty, specifically where they are relatively high—either because of energy inefficiency or higher household need (e.g., large households or households with persons requiring enhanced heating temperatures or heating hours).

Applying this dual criteria approach to Calgary, a household h in geography i at time t is energy poor if (all notation is defined above):

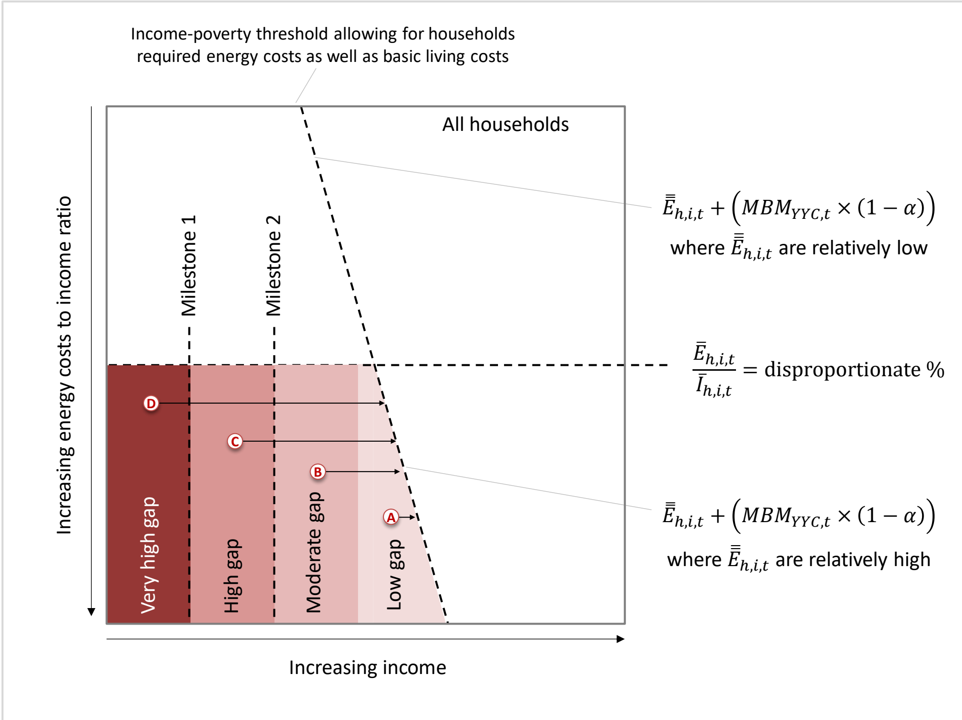
$$\bar{\bar{E}}_{h,i,t} > \bar{\bar{I}}_{h,i,t} - \left(MBM_{YYC,t} \times (1-\alpha) \right)$$

And (both criteria must be satisfied):

$$\frac{\bar{\bar{E}}_{h,i,t}}{\bar{I}_{h,i,t}} > 0.10 = \bar{E}_{h,i,t} > 0.10 \times \bar{I}_{h,i,t}$$

The 10% threshold could be set at a different level, specific to Calgary; for example, it could be set at twice the median expenditure-income ratio for all Calgary households in 2024. The ratio should subsequently be fixed for a period of time to address the shortcomings of a dynamic 2M indicator (recall Section 4.2.3). The combination of the MIS indicator and the 10% ratio indicator is illustrated in Figure 4, showing how the "severity bands" could be used to target interventions and set interim milestones to address energy poverty.

Figure 4: Illustrating the MIS and 10% ratio indicator (Scottish definition of energy poverty)



Moore et al. (2018) suggest that the MIS indicator could also be used as a more "fit-for-purpose" income-poverty threshold in either the LIHC indicator or the LILEE indicator—essentially replacing the AECP threshold. As stated above, the MIS indicator provides a more accurate and meaningful way of determining whether a household can afford their energy bills on top of other basic living costs. Moreover, given the valid criticisms of the energy cost and energy efficiency (FPEER) thresholds used in the LIHC indicator and the LILEE indicator[21]—also discussed above—Moore et al. (2018) and Florian and Sondes (2019) suggest replacing the energy efficiency rating with an alternative normalized expenditure metric that directly reflects the theoretical energy costs of the household in their home. Specifically, Moore et al. (2018) propose replacing the energy cost threshold with a "household-based energy efficiency rating" (or HBEER scale). The proposed HBEER is based on equivalized theoretical unit energy costs per area of floor space (e.g., square metre or square feet). As a result, poorer ratings on the scale are not profoundly biased towards larger dwellings, as they would be with the LIHC indicator (and the energy poverty gap) which is based on total fuel costs. Estimated theoretical unit energy costs per household are transformed onto the HBEER scale, on the interval 0 (low energy costs, low energy efficiency) to 100 (high energy costs, high energy efficiency). As proposed by Moore et al. (2018), the HBEER scale is designed so that a value of 50 on the scale corresponds to the median unit energy cost of all homes; below 50 on the scale unit energy costs increase, while above 50, unit energy costs fall. Furthermore, the HBEER scale is based on the cumulative frequency distribution of all homes; hence, a

[21] For example, the energy costs threshold in the LIHC indicator creates a bias towards larger dwellings resulting in some of the poorest households, least able to afford their energy costs and living in below average sized, energy inefficient homes, to be classified as not being energy poor. While higher income households with adequate energy budgets, who live in larger more energy efficient dwellings, are classified as energy poor.

rating of 75 means that the home is better than 75% and worse than 25% of all homes. Generating the HBEER scale involves:

1. Creating a frequency distribution of unit energy costs for all homes (\$ per ft^2);
2. Transforming the frequency distribution into the cumulative frequency distribution (CDF);
3. Renormalizing the CDF to 100 by taking the difference between 100 and the CDF; and
4. Fitting a backward S-curve to the outcome of the previous step to link unit energy costs (independent variable) with the HBEER scale (dependent variable).

Note that the HBEER scale (the values delineating levels of energy efficiency) can be fixed for a period of time, to enable the evaluation of interventions designed to reduce home energy costs (i.e., tracking the number of households moving from higher to lower values on the scale).

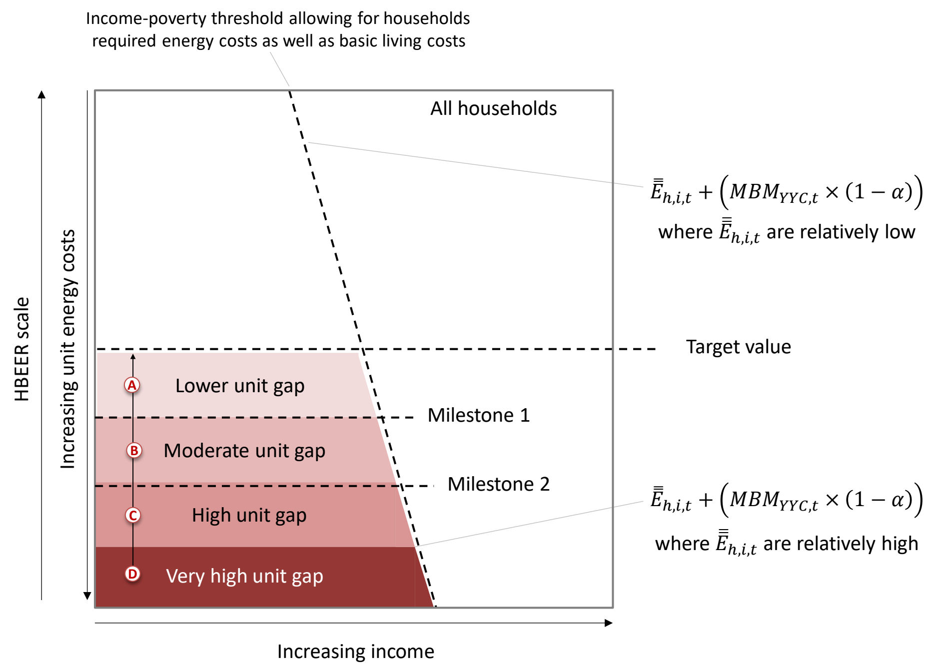
Applying the MIS-HBEER dual criteria approach proposed by Moore et al. (2018) to Calgary, a household h in geography i at time t is energy poor if (all notation is defined above):

$$\bar{\bar{E}}_{h,i,t} > \bar{\bar{I}}_{h,i,t} - \left(MBM_{YYC,t} \times (1 - \alpha) \right)$$

$$HBEER_{h,i,t} < target\ value$$

There is still the problematic issue of setting the target value, whether it is (say) the 30^{th}, 40^{th} or 50^{th} percentile. **The "unit gap" is the HBEER equivalent of the energy poverty gap measured using the LIHC or LILEE indicators**. It measures the extent to which the equivalized total unit energy costs per square foot of a dwelling exceeds the unit costs defined by the fixed target value, such as the 50^{th} percentile value. Households below the target value could be clustered into bands based on the magnitude of their unit energy cost gaps, which would help to improve the targeting of interventions (e.g., prioritizing households with very high unit (energy poverty) gaps) and enable the formulation of interim milestones, as illustrated in Figure 5. The HBEER scale and numerical values delineating the interim milestones and threshold are fixed for a period of time to enable the evaluation of interventions designed to improve the energy efficiency of energy poor households; the number of households crossing defined values on the HBEER scale can be tracked.

Figure 5: Illustrating the MIS and HBEER (unit energy costs) indicator



Source: Adapted from Moore et al. (2018)

5 MEASURMENT OF ENERGY POVERTY IN CALGARY

The main approaches to measuring the prevalence ("headcount") and severity ("depth") of energy poverty in a jurisdiction were identified and critiqued in Section 4. Below, a number of the expenditure-based indicators reviewed are applied to a sample of Census Dissemination Areas (DAs) across diverse communities in Calgary. The numerical outcomes can then be considered in tandem with the identified pros and cons of each indicator from Section 4 to inform a recommended approach for Calgary's Energy poverty Strategy.

5.1 Expenditure-based indicator scenarios

The following expenditure-based indicators and specifications are assessed:

1. **10% ratio indicator (before housing costs)**. Income is measured after tax and before housing costs (i.e., AT-income BHC). Energy costs are estimated annual (fixed and variable) charges for electricity and natural gas consumption. The energy burden threshold used is 10%.
2. **10% ratio indicator (after housing costs)**. As above, except income is measured after tax and *after* housing costs (i.e., AT-income AHC).

3. **2M indicator (before housing costs)**. Energy costs are estimated annual (fixed and variable) charges for electricity and natural gas consumption. Income is measured after tax and before housing costs. The energy burden threshold is set at double the median energy costs to AT-income BHC ratio for the sample of 12 communities (i.e., 6.1%).
4. **2M indicator (after housing costs)**. Energy costs are estimated annual (fixed and variable) charges for electricity and natural gas consumption. Income is measured after tax and after housing costs. The energy burden threshold is set at double the median energy costs to AT-income AHC ratio for the sample of 12 communities (i.e., 7.2%).
5. **After energy cost poverty**. Income is measured after tax and after housing costs. Energy costs are estimated annual (fixed and variable) charges for electricity and natural gas consumption. The income-poverty threshold is defined by the after tax Low-income Cut-Offs (AT-LICO) for centres with a population of 500,000 or more. The LICO-AT is adjusted for the average household size of each DA.
6. **Minimum income standard (MIS)**. Energy costs are estimated annual (fixed and variable) charges for electricity and natural gas consumption; annual energy costs are equivalized using the estimated trend line for Calgary in Figure 6[22]. Income is measured after tax and after housing costs and is equivalized with reference to the average household size of Calgary[23]. The basket of goods and services needed for a basic standard of living is based on the Market Basket Measure (MBM), Canada's official poverty line. The MBM is adjusted to remove "shelter costs". The adjusted MBM is equivalized with respect to the average household size of the DA.
7. **Low-income high cost (LIHC) indicator**. Income is measured after tax and after housing costs and is equivalized with respect to the average household size of Calgary. The income-poverty line is based on the LICO-AT, equivalized with respect to the average household size of Calgary[24]. Annual home energy costs (fixed and variable charges for electricity and natural gas) are equivalized using the estimated trend line for Calgary in Figure 6. The energy cost threshold is set at the 30th percentile energy costs of the full sample of DAs, equivalized with respect to the average household size of Calgary[25].

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[22] Estimated energy costs are based on a range of different building architypes for Calgary, assuming an average household. Equivalization effectively decreases the energy costs for DAs with smaller average household sizes relative to the average for Calgary and increase the energy costs for DAs with larger average household sizes relative to the average for Calgary, with the aim of making households of different sizes vis-à-vis Calgary comparable.

[23] To maintain consistency with estimated energy costs, the average household size in Calgary is taken as the reference household. In this case, equivalization effectively lowers the incomes for households in DAs with smaller average household sizes relative to Calgary and raises the incomes for households in DAs with larger average household sizes relative to Calgary, again with the aim of making households of different sizes vis-à-vis Calgary comparable.

[24] For the purpose of the scenario analysis, the LICO-AT is used as opposed to the official poverty line defined by the MBM. The determination of whether a household is below the appropriate MBM value is based on a comparison with "disposable income", which has a very specific definition and could not be readily calculated within the scope of this project.

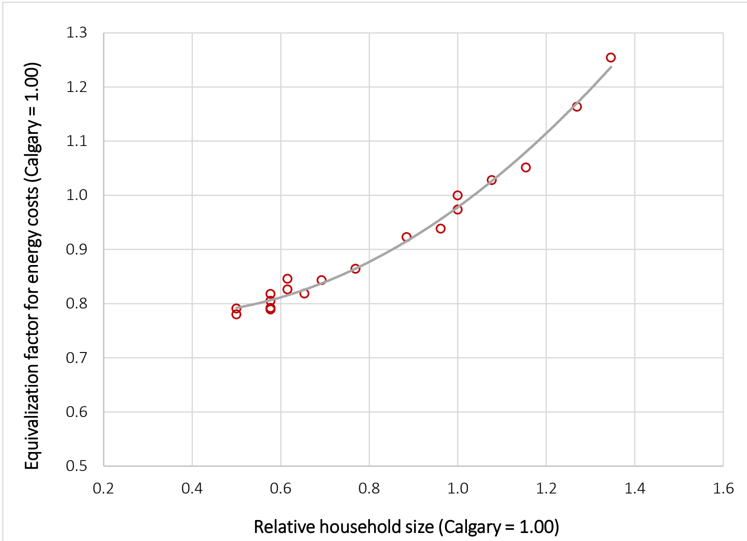
[25] The energy cost threshold in the original LIHC indicator applied in England was set at 50% of the median value; however, this was roundly criticized for being excessively high (recall Section 4.2.5).

8. **Minimum income standard (MIS) and ratio indicator**. A dual criteria indicator combining option 2 and option 6. Though instead of setting the energy cost and income ratio at 10%, it is set at double the contemporary median share of the sample, with income measured AHC (i.e., 7.2%). This threshold would be fixed for a period of time, thus essentially making it an absolute criterion over this period.
9. **Minimum income standard (MIS) and low energy efficiency indicator**. This is a variation of the low-income low energy efficiency (LILEE) indicator with modifications to both threshold criteria. First, the MIS indicator (option 6) is used to replace the income-poverty threshold used in the conventional LILEE indicator. Second, estimated unit energy costs ($ per ft^2 per year) are used instead of the Fuel Poverty Energy Efficiency Rating (FPEER) in the conventional LILEE indicator; the FPEER or similar rating scale is not currently available for Calgary. The unit energy cost threshold is set at the 50^{th} percentile across all DAs in the sample; this is an arbitrary choice.

The equations defining the criterion or criteria used by each indicator to delineate energy poor from non-energy poor households were described in Section 4.2. For this scenario analysis, however, the unit of analysis is not the individual household (denoted by h), as per the above equations. Rather, the unit of analysis is an "income group" (denoted by Y), of which there are 18[26]. Each income group in a specific DA will contain a number of households in accordance with the 2021 Census of the Population. The indicator criterion or criteria are applied to the central values of each income group; specifically, the midpoint of each income group interval. **If the income group is classified as energy poor, then all households in that group are assumed to be energy poor**. This is a necessary assumption in the absence of data on the incomes of individual households within each income group, for each of the DAs included in the analysis. For a selection of DAs and income groups, the median household income was obtained from Statistics Canada; the midpoint of these income groups proved a very good proxy for the median household income. The total number of energy poor households in a DA is then calculated as the sum of energy poor households across all income groups in that DA.

Figure 6: Approximation of energy cost equivalence factor: based on Calgary wide data

[26] The 18 income groups are: under $4,999; $5,000-$9,999; $10,000-$14,999; $15,000-$19,999; $20,000-$24,999; $25,000-$29,999; $30,000-$34,999; $35,000-$39,999; $40,000-$44,999; $45,000-$49,999; $50,000-$59,999; $60,000-$69,999; $70,000-$79,999; $80,000-$89,999; $90,000-$99,999; $100,000-$124,999; $125,000-$149,999; $150,000 and over.



Note: the equation for the fitted line is y = 0.443946*x^2 – 0.294273*x+0.85. "x" is the household size of the DA divided by the average household size in Calgary (i.e., 2.6 persons). "y" is the equivalence (scaling) factor for annual energy costs in the DA. The equivalized annual energy costs for a DA are given by the unequivalized costs divided by the equivalence (scaling) factor.

Taking the 10% ratio indicator (after housing costs) as an example, the number of energy poor households in a DA is calculated as follows:

A household in income group Y in DA i at time t is energy poor if:

$$\frac{\bar{\bar{E}}_{Y,i,t}}{\bar{\bar{I}}_{Y,i,t}} > 0.10 = \bar{\bar{E}}_{Y,i,t} > 0.10 \times \bar{\bar{I}}_{Y,i,t}$$

Where: $\bar{\bar{E}}$ is the estimated energy costs of income group Y in DA i and $\bar{\bar{I}}$ is the average household AT-income after housing costs (AHC) of income group Y in DA i.

And:

$$\bar{\bar{I}}_{Y,i,t} = \left(I_{Y,i,t} - HC_{Y,i,t}\right)$$

Where (for income group Y in DA i): $\bar{\bar{I}}$ is the average household AT-income *after* housing costs, I is the average household AT-income *before* housing costs, and HC are the average non-energy housing costs. The latter is calculated as:

$$HC_{Y,i,t} = \beta_1 \times I_{Y,i,t}^2 + \beta_2 \times I_{Y,i,t} + \beta_3$$

Where: β_1 (-2.904E-07), β_2 (+1.468E-01), and β_3 (+4.893E+03) are estimated parameters for Calgary.

The distribution of annual energy costs for DA i was provided by the City of Calgary (see Appendix A). The annual energy costs of income group Y in DA i are approximated by mapping the cumulative frequency of all households in DA i up to income group Y onto the distribution of annual energy costs. For example, if the cumulative frequency of all households in DA i up to income group Y is 0.60, then it the 60th percentile from the annual energy costs distribution of DA i is assigned to that income group. The minimum annual energy cost for the DA is assigned to the lowest income group for which households are present. Conversely, the maximum annual energy cost for the DA is assigned to the highest income group for which households are present. In effect, the energy costs distribution is made to fit the after tax income distribution—based on the observation that home energy costs are (positively) collinear with AT-income (as shown Figure 7).

The total number of energy poor, EP, households in DA i at time $t = 2021$ is thus given by:

$$EP_{i,t} = \sum_{Y=1}^{18} H_{Y,i,t} \mid \bar{E}_{Y,i,t} > 0.10 \times \bar{\bar{I}}_{Y,i,t}$$

Where: H is the total number of households in income group Y in DA i.

Figure 7: Associated between annual home energy costs and after tax household income in Calgary

5.2 Spatial units

The analysis is performed for 12 Census Dissemination Areas (DAs), which fall within 11 diverse communities in Calgary:

DA 48 06 0091 [Highland Park]	DA 48 06 1168 [Forest Lawn]

DA 48 06 0312 [**Varsity**]	DA 48 06 1215 [**Ogden**]
DA 48 06 0672 [**Richmond**]	DA 48 06 1636 [**Midnapore**]
DA 48 06 0777 [**Oakridge**]	DA 48 06 1674 [**Castleridge**]
DA 48 06 0956 [**Whitehorn**]	DA 48 06 1793 [**Citadel**]
DA 48 06 1091 [**Castleridge**]	DA 48 06 1880 [**Aspen Woods**]

Building-level data was provided by the City of Calgary for a total of 2,444 dwelling units across the sample of 12 DAs. For each dwelling unit, the data set included information on living area, annual electricity and natural gas consumption, annual electricity and natural gas fixed charges, and electricity and natural gas commodity charges. Descriptive statistics for key variables for the sample of 12 DAs are provided in Table 2. The median dwelling unit in the sample data, for example, had an annual energy bill of $3,298, of which $1,810 and $1,488 was for electricity and natural gas, respectively. The corresponding dwelling was 2,178 square feet (ft2), making the energy costs per ft2 equal to $1.51. Appendix A contains the same descriptive statistics for each of the 12 DAs. Income data by DA was downloaded from the 2021 Census of the Population, and combined with shelter cost data, by income group, obtained directly from Statistics Canada.

Table 2: Energy use profile: Sample of case study areas

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444
Mean	2,318	26	119	1,897	1,535	3,431	1.64	27
STDEV	1,230	9	38	551	348	889	0.37	12
Min	326	5	23	603	651	1,254	3.85	100
P10	1,180	17	76	1,357	1,142	2,499	2.12	43
P20	1,366	19	96	1,495	1,323	2,819	2.06	41
P30	1,958	22	103	1,660	1,382	3,042	1.55	24
P40	1,601	23	113	1,697	1,475	3,172	1.98	38
P50	2,178	24	114	1,810	1,488	3,298	1.51	23
P60	2,160	26	120	1,885	1,540	3,425	1.59	25
P70	3,109	27	124	1,970	1,577	3,548	1.14	11
P80	2,450	29	136	2,095	1,688	3,783	1.54	24
P90	4,106	36	163	2,498	1,942	4,441	1.08	9
Max	12,400	101	400	6,466	4,122	10,588	0.85	1
KURT	7.7	7.8	5.6	7.8	5.6	7.0	-0.2	-0.2
SKEW	2.3	2.1	1.7	2.1	1.7	2.0	-0.1	-0.1
Q1	1,645	21	98	1,619	1,338	2,969	1.46	21
Q3	2,536	28	131	2,005	1,644	3,622	1.95	37
IQR	891	6	33	386	306	653	0.48	16

Note: The normalized score is based on the energy bill per unit area of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

5.3 Results

5.3.1 Prevalence and severity of energy poverty

The estimated prevalence ("headcount") and severity ("depth") of energy poverty in the 12 DAs (11 communities) are summarized in Table 3, by indicator. Similar tables are provided in Appendix B for individual DAs. The "best estimate" is presented in the second column; the third, fourth and fifth column contain the 10th, 50th, and 90th percentile values, respectively. Note that for all indicators the percentile values correspond to the 10th, 50th, and 90th percentile of the annual energy costs distribution. Regarding the LILEE + MIS indicator—which is driven by energy costs per ft^2—this means that headcounts for the 90th percentile, for instance, are not necessarily larger than for the 10th percentile. This is because the energy costs per ft^2 corresponding to the 90th percentile energy bill are lower than the energy costs per ft2 corresponding to the 10th percentile energy bill.

Figure 8: Frequency distribution of annual home energy costs for electricity and natural gas consumption by case study area

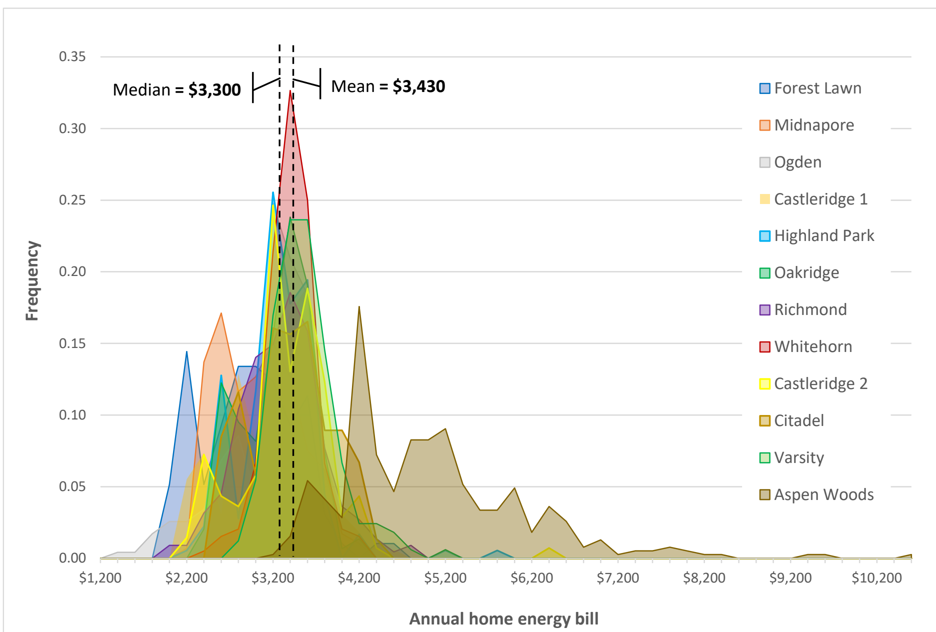
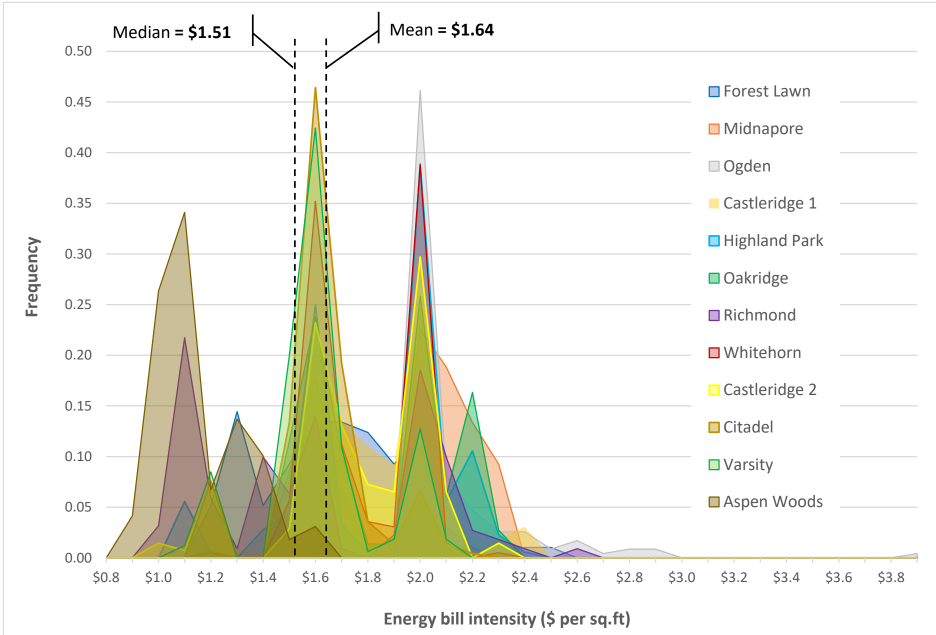


Figure 9: Frequency distribution of energy cost intensity by case study area



Although the first four indicators have the same structure, as expected, the more stringent thresholds of the first two indicators (at 10%) result in fewer households being labelled energy poor (4%-10% of all households), compared with the 2M indicators with lower thresholds (17%-21% of all households). The results show that the inclusion of housing costs in the calculation lowers the after-tax incomes available to pay for energy costs, which increases the number of energy poor households. With the 10% ratio indicators, for instance, the headcount increases from 105 (4% of all households) to 275 (21%) households by including housing costs in the income calculation.

Comparing the two 2M indicators, even though the first indicator has a lower threshold than the second indicator, 6.1% vs 7.2%, it results in a smaller number of households being labelled energy poor (445 vs 560). This is because **income is measured after housing costs**. Typically, a lower threshold would mean more households are classified as energy poor, other things being equal. However, in this case, the inclusion of housing costs in the calculation of income more than compensates for a threshold that is 1.1 percentage points higher. Note that the median share that serves as the basis for calculating the percentage thresholds is also calculated before and after housing costs; this is why the thresholds values differ between the two 2M indicators.

As the threshold is lowered (e.g., from 10% to 7.2%), households with (much) higher incomes and (slightly) higher energy costs are classified as energy poor. For example, the average incomes (AT-income, AHC) of energy poor households are $15,210 under the 10% ratio indicator but $26,605 under the 2M indicator (with the threshold at 7.2%). Corresponding average home energy costs are $2,435 and $2,780. The average energy costs to income ratio (AT-income, AHC) of all energy poor households using the 10% threshold is thus 16% ($2,435 / $15,210); in contrast, the average energy burden of all energy poor households using the 7.2% threshold is 10.4% ($2,780 / $26,605).

A weakness of these four ratio indicators, as explained in Sections 4.2.2 and 4.2.3, is they do not have an income threshold and thus capture a significant proportion of households that are not in poverty. For example, of the 560 households identified as energy poor using the 2M [AT-income, AHC] indicator, 330 or 59% had AT-incomes above the after tax LICO. The after energy cost poverty (AECP) indicator is designed to address this problem and does to some extent. There are 35 higher income households classified as energy poor under the 2M [AT-income, AHC] indicator that are no longer considered energy poor using the AECP indicator. The average income (AT-income, AHC) of those households no longer considered energy poor is $49,255, with average home energy costs of $3,820. As expected, with the removal of these households from the energy poor headcount, the average income (AT-income, AHC) of energy poor households and corresponding energy costs using the AECP indicator ($23,970 and $2,585, respectively) are lower than under the 2M [AT-income, AHC] indicator. It follows that the average affordability ratio of energy poor households is also higher; 10.8% compared with 10.4%. For contrast, the average affordability ratio of those households now removed from the energy poor headcount is 7.8% (average income and home energy costs of, respectively, $49,255 and $3,820).

Table 3: Estimated energy poverty headcount and depth by indicator: sample of 12 DAs

Indicator [specification of criteria]	Best est.	10 P energy bill	50 P energy bill	90 P energy bill
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	105	120	205	260
% of total households	4%	4%	8%	10%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	275	240	410	495
% of total households	10%	9%	15%	18%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	445	350	525	760
% of total households	17%	13%	20%	28%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	560	450	670	790
% of total households	21%	17%	25%	29%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	525	530	530	550
% of total households	20%	20%	20%	20%
MIS [based on adj., equival. MBM]				
No. of households energy poor	415	365	415	415
% of total households	15%	14%	15%	15%
Energy poverty gap - total	$4,325,062	$4,405,511	$4,598,681	$4,817,396
Energy poverty gap - average	$10,422	$12,070	$11,081	$11,608
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	135	95	400	480
% of total households	5%	4%	15%	18%
Energy poverty gap - total	$33,981	$48,958	$182,890	$424,573
Energy poverty gap - average	$252	$515	$457	$885
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	410	365	415	415
% of total households	15%	14%	15%	15%
Energy poverty gap	$4,462,650	$4,464,092	$4,738,181	$4,954,725
Energy poverty gap - average	$10,885	$12,230	$11,417	$11,939
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	355	365	415	415
% of total households	13%	14%	15%	15%
Unit energy poverty gap - total	$181,061	$371,084	$276,435	$242,066
Unit energy poverty gap - average	$510	$1,017	$666	$583

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

The LIHC indicator combines the AECP indicator with an energy cost constraint. Hence, the headcount of energy poor households is expected to be lower; 135 households compared to 525 households, as shown in Table 3. Even with the energy cost threshold set at the 30th percentile value across the sample of DAs (in contrast to the standard 50th percentile), a significant number of energy poor households using the AECP indicator are removed from the headcount with the LIHC indicator. All of these excluded households have home energy costs lower than the 30th percentile threshold value, but also have relatively low incomes. Is that a desirable outcome? Consider: The average income (AT-income, AHC) of those households no longer considered energy poor using the LIHC indicator compared with the AECP indicator is $22,095 with average home energy costs of $2,490. The energy burden for these households is thus 11.3%. This is relatively high—certainly higher than the 2M indicator thresholds (6.1% and 7.2%) and the 10% ratio indicator threshold. It is hard to justify not classifying these household as energy poor, suggesting the LIHC indicator is overly stringent.

The energy poor headcount using the MIS indicator is 415 (or 15% of total households in the sample). The average income (AT-income, AHC) of these energy poor households is $20,195 with corresponding average home energy costs of $2,522. The average affordability ratio of all energy poor households is thus 12.5%. Relative to the 2M, AECP and LIHC indicators, the MIS indicator is capturing lower income households with higher affordability concerns (energy cost burdens). Compared with the AECP indicator, the MIS indicator classifies 110 fewer households as energy poor. The average income (AT-income, AHC) and home energy costs of these excluded households are $38,210 and $2,830, respectively. The corresponding energy affordability ratio is 7.4%. The MIS indicator is thus removing higher income households with lower affordability concerns from the headcount.

The addition of an energy cost constraint to the MIS indicator has negligible impact on the headcount of energy poor households in the sample of DAs; reducing the number from 415 to 410. This is largely due to the characteristics of the dataset with the 2M energy affordability threshold across the sample of households equal to 7.2%. If the cost threshold is higher, then the difference between the estimated headcounts would be greater than five (fewer households would be considered energy poor using this dual criteria indicator). The energy burden of the five excluded households is 7.1%, which is just under the threshold of 7.2%.

The final indicator considered—the LILEE indicator—combines a different form of energy cost constraint with the MIS indicator. In this case, estimated unit energy costs ($ per ft^2 per year) are used to define the energy cost threshold, which is set at the 50th percentile ($1.51 per ft^2 per year) across all DAs in the sample. The energy poor headcount using this dual criteria indicator is 355 (or 13% of total households in the sample). In this case, the unit energy cost constraint is relatively more stringent than the 2M energy cost threshold, reducing the number of energy poor households using the MIS alone by 60 households (or 15%), as opposed to only five (or 1%). The average income (AT-income, AHC) of the 355 energy poor households is $19,205 with corresponding average home energy costs of $2,490; hence, the average affordability ratio of these energy poor households is 13.0%. This is slightly higher than the burden faced by energy poor households using the MIS and 2M dual criteria indicator at 12.6%. However, while the energy affordability ratio of those households excluded with the addition of the 2M cost threshold to the MIS indicator is 7.1%, those households excluded with the addition of the unit energy cost constraint is 10.4% (average income and home energy costs of, respectively, $26,045 and $2,705); considerably higher. This suggests that the LILEE indicator excludes households from the energy poor headcount that might be considered to face excessive energy cost burdens, which is not a desirable outcome.

Table 4: Estimated energy poverty gap by DA and relevant indicator

Indicator	48 06 0091 Highland Park	48 06 0312 Varsity	48 06 0672 Richmond	48 06 0777 Oakridge	48 06 0956 Whitehorn	48 06 1091 Castleridge	48 06 1168 Forest Lawn	48 06 1215 Ogden	48 06 1636 Midnapore	48 06 1674 Castleridge	48 06 1793 Citadel	48 06 1880 Aspen Woods
MIS [based on adj., equival. MBM]												
Rank - total gap (12 = largest)	11	1	4	9	7	6	12	10	8	3	2	5
Rank - average gap (12 = largest)	5	1	4	8	9	10	12	7	6	3	2	11
Energy poverty gap - total	$674,932	$546	$201,590	$400,435	$344,879	$242,896	$1,162,804	$627,555	$355,861	$56,437	$49,859	$207,269
Energy poverty gap - average	$8,437	$109	$6,720	$11,441	$11,496	$12,145	$16,611	$9,655	$8,897	$5,644	$3,324	$13,818
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]												
Rank - total gap (12 = largest)	8	6	1	9	12	10	1	4	1	5	7	11
Rank - average gap (12 = largest)	4	9	1	7	11	10	1	5	1	8	6	12
Energy poverty gap - total	$509	$337	$0	$792	$16,545	$2,367	$0	$215	$0	$269	$395	$12,552
Energy poverty gap - average	$17	$67	$0	$53	$552	$158	$0	$22	$0	$54	$40	$837
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]												
Rank - total gap (12 = largest)	11	1	6	9	7	5	12	10	8	2	3	4
Rank - average gap (12 = largest)	7	1	4	10	6	9	12	8	5	3	2	11
Energy poverty gap	$803,384	$542	$240,330	$411,782	$290,985	$208,114	$1,229,369	$675,216	$370,855	$21,103	$23,593	$187,378
Energy poverty gap - average	$10,042	$108	$8,011	$11,765	$9,700	$10,406	$17,562	$10,388	$9,271	$4,221	$1,573	$12,492
LILEE [MIS as above & P50 unit energy costs for sample]												
Rank - total gap (12 = largest)	8	3	2	10	6	7	11	12	9	5	4	1
Rank - average gap (12 = largest)	6	7	3	12	4	5	8	11	9	10	2	1
Unit energy poverty gap - total	$19,627	$2,411	$2,228	$26,289	$7,144	$7,701	$33,821	$48,659	$23,076	$6,034	$2,846	$1,225
Unit energy poverty gap - average	$393	$482	$223	$751	$238	$385	$564	$749	$577	$603	$190	$82

Table 3 also provides estimated measures of the severity (or depth) of energy poverty; labelled as an "energy poverty gap". As noted in Section 1.2.1, this mirrors term used in the UK ("fuel poverty gap")[27]. This gap can be viewed as a monetary measure of the financial burden faced by households in energy poverty. Both the total (aggregate) burden across all energy poor households and the average burden of an energy poor household are provided. As explained in Sections 4.2.5, 4.2.6 and 4.2.7, the definition and calculation of the "gap" is different between indicators; only the estimated gaps for the MIS indicator and the MIS-2M dual criteria indicator are comparable in Table 3 (i.e., they are measuring the same thing).

With the LIHC indicator, the energy poverty gap measures the difference between an energy poor household's energy costs and what is determined to be affordable for that household; the larger the gap, the greater the difference. What is deemed to be affordable is defined as the energy bill that removes a household from energy poverty, either by moving it below the energy cost threshold (i.e., costs less than the 30th percentile sample household) or above the income-poverty threshold (i.e., having residual income after paying energy costs greater than the LICO-AT). The estimated energy poverty gap for energy poor households using the LIHC indicator is $33,980 or about $250 per household.

The "unit gap" in the LILEE indicator measures the extent to which the total unit energy costs per ft^2 of an energy poor dwelling is higher than the unit costs defining the cost threshold (in this case, $1.51 per ft^2). Across all energy poor households under the LILEE indicator, the total reduction in annual energy costs required to remove households in the sample of DAs out of energy poverty is $181,060 or $510 per household, all else being equal. For these energy poor households, the MIS-based energy poverty gap (see below) can also be calculated, though it is not shown here.

The total energy poverty gap for the dual MIS and 2M indicator is substantially larger than the calculated gaps for the LILEE and LIHC indicators. This is because it measures the total extent to which the AT-income of an energy poor household is insufficient to afford housing costs, home energy costs, and living costs for a basic standard of living. However, the total energy poverty gap can be decomposed into various components with more explicit policy relevance.

With the dual MIS and 2M indicator a household can be energy poor because either:

1. The household has insufficient income (AT-income, AHC) to afford basic living costs[28] regardless of its energy costs. In this case, paying energy bills lowers the economic wellbeing of the household (makes them worse-off) as they must sacrifice other basic needs to afford their bills; or
2. The household has enough income (AT-income, AHC) to afford all basic living costs before paying its energy bill, but once they pay their energy bill, they can no longer meet all other basic needs. [29] This means the household is pushed into energy poverty by paying its energy bills.

[27] In the US, the term "energy affordability gap" is preferred.

[28] Formally, $\bar{\bar{I}}_{h,i,t} < \left(MBM_{YYC,t} \times (1-\alpha) \right)$ even when $\bar{\bar{\bar{E}}}_{h,i,t} = 0$. When $\bar{\bar{\bar{E}}}_{h,i,t}$ is some amount greater than zero, $\bar{\bar{I}}_{h,i,t} - \bar{\bar{\bar{E}}}_{h,i,t} \ll \left(MBM_{YYC,t} \times (1-\alpha) \right)$.

[29] Formally, $\bar{\bar{I}}_{h,i,t} > \left(MBM_{YYC,t} \times (1-\alpha) \right)$ even when $\bar{\bar{\bar{E}}}_{h,i,t} = 0$. When $\bar{\bar{\bar{E}}}_{h,i,t}$ is some amount greater than zero, $\bar{\bar{I}}_{h,i,t} - \bar{\bar{\bar{E}}}_{h,i,t} < \left(MBM_{YYC,t} \times (1-\alpha) \right)$.

Looking at the second group of households (2 above) first, the average (and total) so-called "energy bill affordability gap" can be calculated; this is given by the reduction in a household's energy costs necessary to remove it from energy poverty, or put another way, the basic living expenditures a household must forgo to avoid being energy poor. For energy poor households, the energy bill affordability gap is equal to:

> The modelled (theoretically required) home energy bill *less* the "affordable" home energy bill. Where the latter is the bill commensurate with 7.2% of AT-income, AHC (i.e., the2M threshold for the sample of 12 DAs).

With the dual MIS and 2M indicator, about 7% of energy poor households in the sample of DAs fall into this category, with an average energy bill affordability gap of $320 per household (the total energy affordability bill gap is about $8,820).

Regarding both groups of households (1 and 2 above), it is possible to differentiate between: (a) how much of the average (and total) energy poverty gap is due to insufficient income; and (b) the extent to which the household's economic wellbeing is reduced by paying its energy bills (i.e., the value of other basic living necessities the household must forgo if it first pays its energy bills).[30] The average energy poverty gap of $10,885 (total equal to $4,462,650) across all 410 energy poor households with the dual MIS and 2M indicator decomposes into: for (a) $9,095 per household ($3,729,325 in total) and for (b) $1,790 per household ($733,325 in total). Note that **the latter value includes the "energy bill affordability gap"**.

By examining the average energy bill gap and energy poverty gap for different DAs, the severity of the problem can be compared and used to inform priorities for targeting interventions. Table 4, which shows the estimated total and average energy poverty gaps for each individual DA in the sample, could be used to prioritize programming efforts. Using the MIS and 2M dual indicator, for example, the following communities might be considered priorities for interventions based on a combination of headcount and total and average energy poverty gaps (in descending order of priority): Forest Lawn, Highland Park, Ogden, and Oakridge.

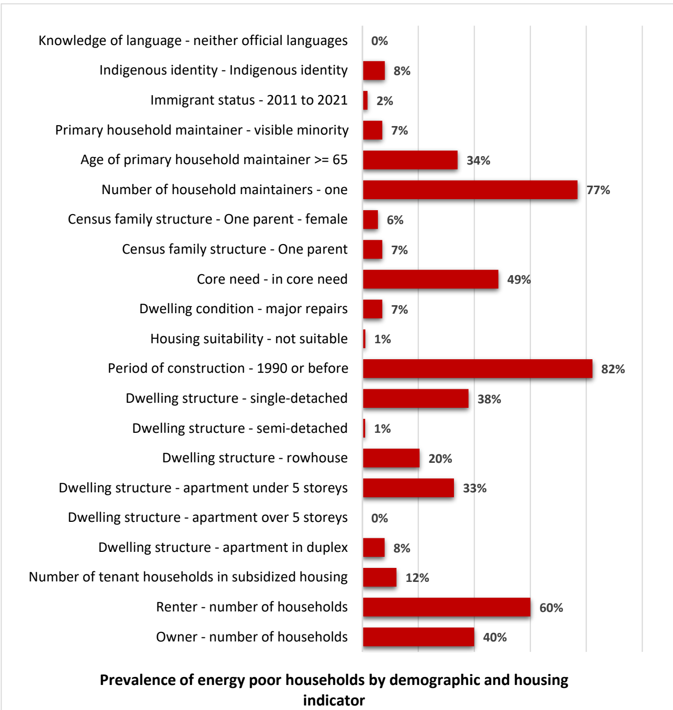
5.3.2 Demography of energy poor households

The design and targeting of interventions within priority communities can be further informed by developing an understanding of the characteristics of energy poor households in the most vulnerable DAs. A set of demographic, dwelling characteristics, and socioeconomic determinants of the likelihood that a households is energy poor were identified from the literature. Data for these determinants was obtained from the 2021 Census of the Population at the Census Tract geography for Calgary and used to create profiles of households (e.g., the % of households in core housing need, the % of dwellings constructed in 1980 or before, the % of one parent census families, the % of renters, etc.) in each after-tax income group (e.g., <$5,000, $5,000-$9,999, etc.) for each DA in the sample. This information was combined with estimates of the number of energy poor households by income group in each DA to create an aggregate picture of all energy poor households by DA and indicator. By way of example, the characteristics of energy poor households in Ogden under four measurement metrics is provided in Figure 10.

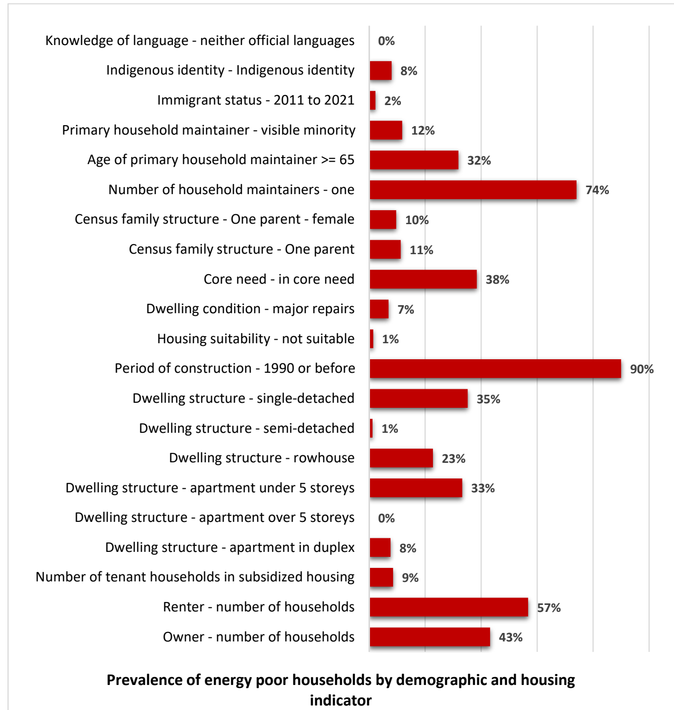
[30] Formally, for all households classified as energy poor, the energy poverty gap (EPG) balances the following equality: $\bar{\bar{I}}_{h,i,t} + EPG = \left(MBM_{YYC,t} \times (1-\alpha) \right) + \bar{\bar{E}}_{h,i,t}$

Figure 10: Demography of energy poor households in Odgen [DA 48061215], by select indicator

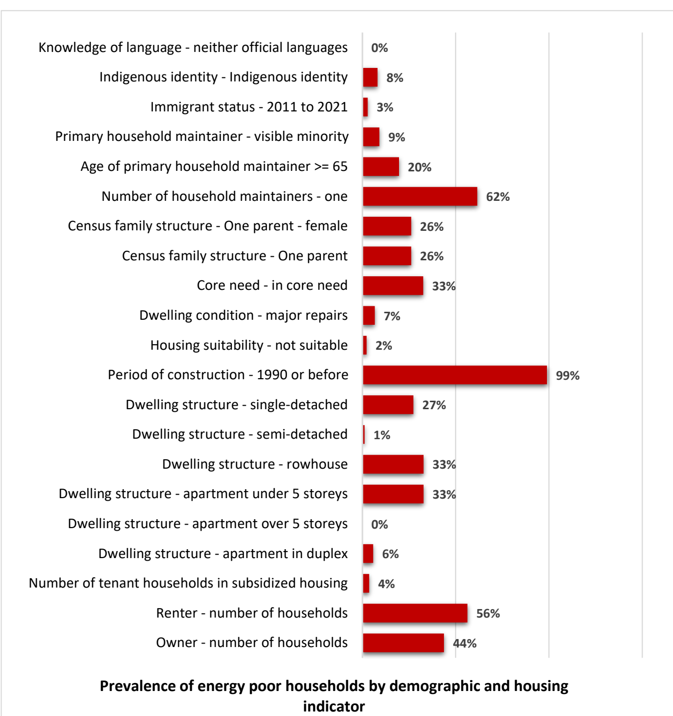
(a) 10% ratio [AT-I AHC]



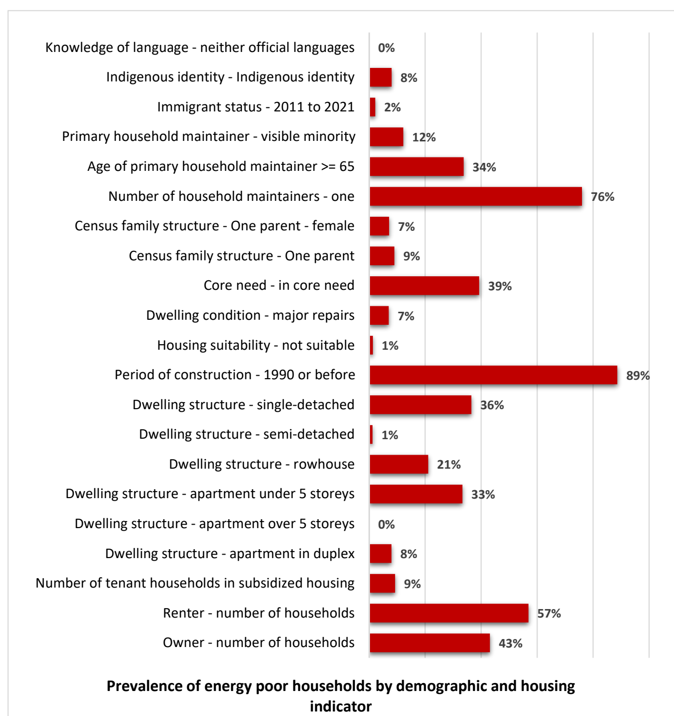
(b) 2M [AT-I AHC]



(c) LIHC



(d) MIS & 2M [AT-I AHC]



Looking at the dual MIS and 2M indicator (in panel d), of those households identified as energy poor in Ogden:

- 89% live in dwellings constructed in 1990 or before;
- 76% have only one household maintainer;
- 57% are renters, of which 9% live in subsidized housing;
- 39% are in core housing need;
- 36% live in single-detached dwellings;
- 33% live in apartments with under five storeys; and
- 34% of the primary household maintainer are 65 years or older.

6 RECOMMENDED APPROACH

It is evident from the above discussion and analysis that it is difficult to identify a single, best indicator for measuring energy poverty. The various indicators evaluated provide different pieces of evidence and have different strengths and weaknesses. Indeed, Boardman's conclusion from 2012 still holds true today: "*the perfect definition of energy poverty is proving elusive*."

It is recommended that the dual criteria MIS and contemporary 2M indicator are considered for implementation in Calgary. This is based on the critique of expenditure-based approaches for measuring the prevalence of energy poor households presented in the previous sections, the wish to have an indicator that also captures the depth of energy poverty, and the results from the application of these approaches to a selection of DAs in Calgary.

The recommended option is designed to address the main shortcomings of Boardman's original 10% ratio indicator, without losing the link to this indicator and its basis in the affordability of home energy costs. The energy burden ratio of the 2M indicator (set at twice the median share for Calgary) should also be fixed in the short term—e.g., it could be reviewed at five-year intervals, corresponding to updates to the Census of the Population. This addresses concerns associated with the dynamic version of the 2M indicator (recall Section 4.2.3).

For the reasons set out in Section 4.2, it is recommended that:

- Income is measured after tax and after housing costs; and
- Household energy costs and income are adjusted for household size and composition (i.e., equivalized) when household-level metrics are compared with population-level metrics (e.g., the MBM for Calgary).

6.1 Dual 2M (energy affordability) and MIS indicator

With this indicator, a household in Calgary would be considered energy poor if:

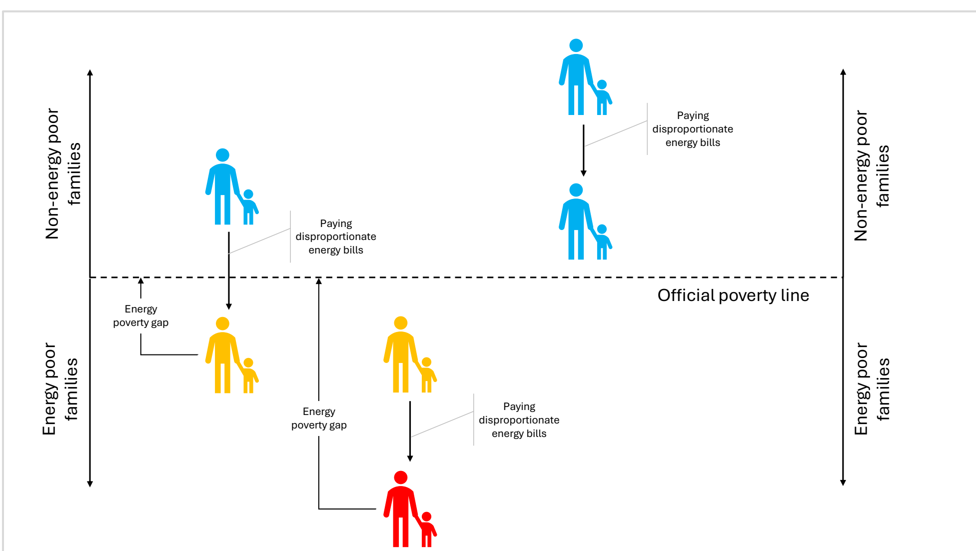
1. It needs to spend more than X% (with X equal to twice the median share for all households in Calgary) of their AT-income, AHC on electricity and natural gas to attain a satisfactory level[31] of energy services; and
2. If these home energy costs and other housing costs were deducted from their after-tax income, they would have insufficient residual income to pay for other living costs to have a basic standard of living as defined by the MBM (official poverty line) for Calgary.

In other words, a household in Calgary should be able to afford adequate heating and electricity needed for a decent quality of life, without being pushed into poverty. After a household has paid for their housing, it is considered energy poor if it needs more than X% of its remaining income to pay its energy bills, and in doing so, it is unable to afford a basic satisfactory standard of living.

Layman's definition: [Option 1] A household in Calgary is considered energy poor if their disproportionate energy bill pushes them into poverty or deepens their poverty. [Option 2] A household in Calgary is considered energy poor if their disproportionate energy bill pushes them into poverty or makes it harder to afford a basic standard of living.

Note: the layman's description has to capture two possibilities: 1. A disproportionate energy bill experienced by a household already in poverty, in which case their situation gets worse from paying the bill; and 2. A disproportionate energy bill experienced by a household not currently in poverty, but that is pushed into poverty from paying the bill. These two possibilities are illustrated in Figure 11. The outcomes from applying the recommended measurement indicator to the sample of DAs is shown in Figure 12 (also recall Figure 4).

Figure 11: Illustrating the recommended definition of energy poverty for Calgary



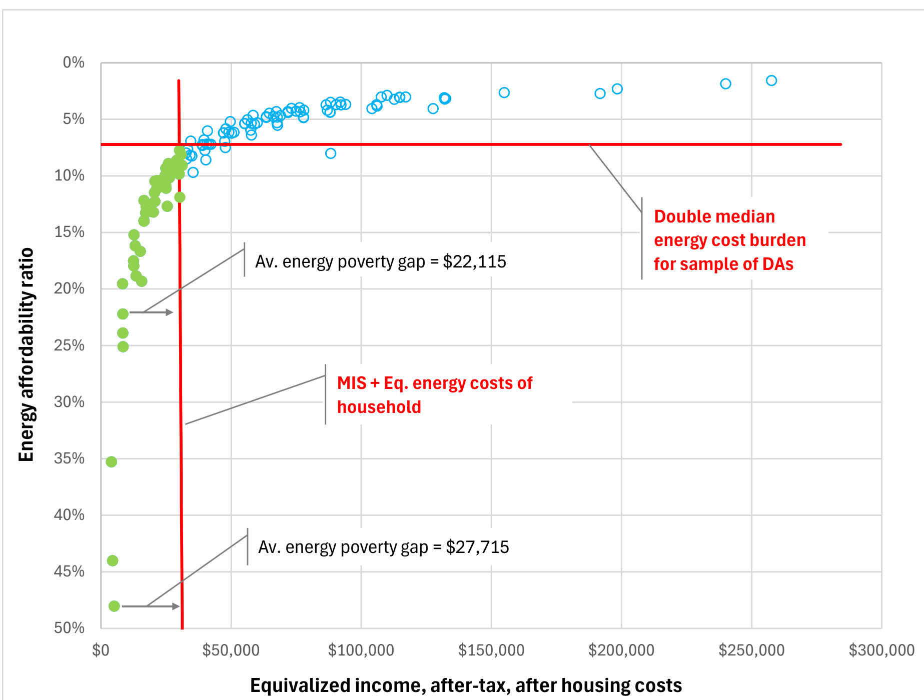
Broadly speaking, the construction and implementation of energy poverty indicators must confront two issues: false positives and false negatives. False positives refer to cases in which a household is classified

[31] This is typically defined with reference to specific temperature thresholds below which people's health, thermal comfort and wellbeing is compromised; for example, the World Health Organization recommends temperature settings of 21°C for the main living areas and 18°C for all other rooms as minimums thresholds for able-bodied healthy households.

as energy poor when they are not. This is a major criticism of the 10% ratio indicator and the 2M indicator on its own. This type of error is expected to be most relevant to the mid to upper ranges of the income distribution. The inclusion of the MIS criterion in the recommended dual criteria indicator addresses these concerns by removing higher income households with lower affordability concerns from the estimated headcount. False negatives refer to cases in which a household is not classified as energy poor, when it is. This is a major criticism of the LIHC indicator, which results in relatively low energy poor headcounts. Theories of energy justice would prioritize the avoidance of false negatives over false positives; it is better to avoid excluding energy poor households than including households that are not energy poor. As explained in Section 4.2.7, of all the expenditure-based indicators reviewed, the MIS criterion is most closely aligned with the concept of energy justice in terms of capturing the impact of home energy costs on material and social deprivations—i.e., social norms about what people need and should not go without to meet essential energy needs. The use of the 2M energy affordability criterion to complement the MIS criterion ensures that home energy costs are explicitly recognized in the measurement of energy poverty, without the problem of false positives.

With the recommended dual criteria indicator, the severity or depth of energy poverty is given by a range of "gap" measures that were described in Section 5.3.1.; this included the total and average energy poverty gap and energy bill gap. It is recommended that energy poor households are clustered into "severity bands" on the basis of their estimated *average* energy poverty or energy bill affordability gap—ranging from "low gap" through "very high gap" (recall Figure 4 and the discussion relating to Table 4). In conjunction with an understanding of the demography of energy poor households, this can serve to guide policy formulation, targeting and the setting of milestone goals for the Energy poverty Strategy.

Figure 12: Summary of results for minimum income standard (MIS) and ratio indicator (green markers represent energy poor households in a DA within a common income grouping)



6.2 Additional considerations

While the recommended dual criteria indicator is more than able to provide estimates of the extent, severity, geography, and broad demography of energy poverty in Calgary—while minimizing the risk of false positives and false negatives—they still have limitations.

In requiring precise information on household income and theoretical energy costs the recommended indicator is dependent on metrics which in fact cannot be measured precisely on the doorstep. Hence the link between the proposed definition, policy interventions and delivery to specific individuals or households can be somewhat tenuous. Undoubtedly, this is a problem with all expenditure-based indicators, though less so with the recommended dual indicator. Broadly speaking, any decisions regarding who should be included or excluded from policy and program interventions should ideally be informed by additional evidence, such as the demography of identified energy poor households. This in turn will facilitate the identification of relevant "community-based organizations" to partner with to help design and implement targeted interventions.

Furthermore, it is only the self-reported approaches (recall Section 4.1) to defining energy poverty that grapple with what it means to be energy poor, capturing issues of inequality, social justice and the lived experience of being energy poor. These issues too should have a role in guiding Strategy, policies, and program interventions. In that sense, a combination of expenditure-based (technical) and self-reported (consensual) indicators would provide a more rounded approach.

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8 APPENDIX A: CASE STUDY ENERGY USE PROFILES

Table 5: Energy use profile: DA 48 06 0091 [Highland Park]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	180	180	180	180	180	180	180	180
Mean	1,833	23	107	1,708	1,425	3,133	1.78	32
STDEV	476	4	23	256	210	455	0.30	10
Min	935	13	66	1,126	1,045	2,170	2.32	50
P10	1,130	16	73	1,314	1,112	2,426	2.15	44
P20	2,682	23	73	1,732	1,110	2,841	1.06	8
P30	1,932	22	101	1,642	1,370	3,012	1.56	24
P40	1,984	22	104	1,678	1,395	3,072	1.55	24
P50	1,592	22	112	1,689	1,470	3,159	1.98	38
P60	1,636	23	115	1,727	1,498	3,225	1.97	38
P70	1,705	24	120	1,786	1,543	3,329	1.95	37
P80	1,782	25	125	1,852	1,593	3,444	1.93	37
P90	1,859	26	131	1,918	1,642	3,560	1.92	36
Max	4,169	47	218	3,168	2,447	5,615	1.35	17
KURT	2.7	7.1	3.7	7.1	3.7	6.0	-0.3	-0.3
SKEW	1.0	1.1	0.8	1.1	0.8	1.1	-0.6	-0.6
Q1	1,589	22	96	1,638	1,321	2,905	1.54	24
Q3	2,031	25	122	1,842	1,565	3,412	1.98	38
IQR	442	3	27	204	244	507	0.44	15

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 6: Energy use profile: DA 48 06 0312 [Varsity]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	165	165	165	165	165	165	165	165
Mean	2,268	26	122	1,902	1,563	3,466	1.56	25
STDEV	488	4	17	223	159	380	0.21	7
Min	1,286	18	90	1,427	1,272	2,698	2.10	42
P10	1,952	22	102	1,656	1,379	3,035	1.55	24
P20	2,067	23	108	1,734	1,435	3,169	1.53	23
P30	2,140	24	112	1,784	1,470	3,254	1.52	23
P40	2,880	25	115	1,849	1,494	3,343	1.16	11
P50	2,957	26	118	1,890	1,522	3,412	1.15	11
P60	1,826	26	128	1,890	1,621	3,511	1.92	36
P70	2,430	27	127	1,982	1,609	3,591	1.48	22
P80	3,241	28	129	2,040	1,626	3,666	1.13	10
P90	3,576	31	142	2,218	1,748	3,966	1.11	9
Max	4,949	43	197	2,945	2,251	5,196	1.05	7
KURT	5.9	3.0	2.5	3.0	2.5	2.8	0.6	0.6
SKEW	1.8	1.3	1.2	1.3	1.2	1.2	0.1	0.1
Q1	1,932	24	111	1,758	1,462	3,227	1.49	22
Q3	2,446	27	130	1,989	1,638	3,613	1.62	26
IQR	514	4	19	231	176	386	0.13	4

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 7: Energy use profile: DA 48 06 0672 [Richmond]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	221	221	221	221	221	221	221	221
Mean	2,240	24	105	1,800	1,404	3,204	1.55	24
STDEV	698	5	26	288	237	483	0.41	14
Min	700	10	49	924	892	1,817	2.60	59
P10	2,416	21	66	1,592	1,043	2,636	1.09	9
P20	1,356	19	95	1,487	1,317	2,804	2.07	41
P30	1,467	21	103	1,582	1,389	2,971	2.02	40
P40	2,984	26	81	1,890	1,185	3,076	1.03	7
P50	1,627	23	114	1,719	1,492	3,211	1.97	38
P60	1,692	24	119	1,775	1,534	3,309	1.96	37
P70	1,794	25	126	1,862	1,600	3,463	1.93	37
P80	2,396	27	125	1,959	1,593	3,552	1.48	22
P90	3,322	29	132	2,083	1,655	3,738	1.13	10
Max	3,432	39	180	2,666	2,092	4,757	1.39	19
KURT	-0.5	0.8	-0.3	0.8	-0.3	0.7	-1.2	-1.2
SKEW	0.2	0.0	0.1	0.0	0.1	0.2	0.2	0.2
Q1	1,679	22	81	1,635	1,185	2,898	1.10	9
Q3	2,740	27	125	1,954	1,588	3,523	1.95	37
IQR	1,061	5	44	319	402	625	0.85	28

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 8: Energy use profile: DA 48 06 0777 [Oakridge]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	147	147	147	147	147	147	147	147
Mean	1,806	23	109	1,702	1,445	3,147	1.80	32
STDEV	429	4	18	233	162	393	0.26	9
Min	1,015	14	71	1,194	1,096	2,290	2.26	47
P10	1,207	17	85	1,359	1,221	2,579	2.14	43
P20	1,324	19	93	1,459	1,296	2,755	2.08	42
P30	1,456	21	102	1,572	1,382	2,954	2.03	40
P40	1,904	23	105	1,700	1,410	3,110	1.63	27
P50	2,119	24	111	1,770	1,460	3,229	1.52	23
P60	1,694	24	119	1,776	1,536	3,312	1.96	37
P70	2,237	25	117	1,850	1,517	3,367	1.51	23
P80	2,340	26	123	1,920	1,566	3,487	1.49	22
P90	2,433	27	127	1,984	1,611	3,595	1.48	22
Max	2,232	32	157	2,238	1,884	4,122	1.85	34
KURT	-0.5	-0.6	-0.7	-0.6	-0.7	-0.7	-1.4	-1.4
SKEW	0.1	-0.3	-0.2	-0.3	-0.2	-0.3	0.0	0.0
Q1	1,473	20	96	1,524	1,318	2,838	1.53	23
Q3	2,137	26	122	1,875	1,561	3,432	2.01	39
IQR	664	6	26	351	243	594	0.48	16

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 9: Energy use profile: DA 48 06 0956 [Whitehorn]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	196	196	196	196	196	196	196	196
Mean	1,933	24	116	1,792	1,508	3,300	1.73	30
STDEV	265	3	14	155	126	278	0.20	7
Min	1,060	15	75	1,233	1,125	2,358	2.22	46
P10	1,921	22	101	1,635	1,364	2,999	1.56	24
P20	1,997	22	105	1,686	1,401	3,087	1.55	24
P30	2,079	23	109	1,742	1,440	3,183	1.53	23
P40	2,156	24	113	1,795	1,478	3,272	1.52	23
P50	2,207	25	116	1,830	1,502	3,332	1.51	23
P60	2,110	25	117	1,849	1,514	3,364	1.59	25
P70	1,777	25	125	1,848	1,589	3,437	1.93	37
P80	1,824	26	128	1,888	1,620	3,508	1.92	36
P90	1,889	27	133	1,944	1,662	3,605	1.91	36
Max	2,199	31	155	2,210	1,862	4,072	1.85	34
KURT	1.1	1.5	0.5	1.5	0.5	1.1	-1.4	-1.4
SKEW	0.5	-0.4	-0.4	-0.4	-0.4	-0.4	0.0	0.0
Q1	1,749	23	107	1,701	1,423	3,124	1.54	24
Q3	2,105	26	125	1,879	1,593	3,473	1.93	37
IQR	356	3	18	178	170	349	0.39	13

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 10: Energy use profile: DA 48 06 1091 [Castleridge]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	138	138	138	138	138	138	138	138
Mean	1,980	24	113	1,766	1,476	3,242	1.71	29
STDEV	688	5	23	324	216	536	0.26	9
Min	1,104	13	61	1,122	1,002	2,124	1.92	36
P10	1,409	17	78	1,342	1,157	2,500	1.77	31
P20	1,739	21	96	1,581	1,325	2,907	1.67	28
P30	1,507	21	106	1,616	1,415	3,031	2.01	39
P40	1,904	23	105	1,700	1,410	3,110	1.63	27
P50	1,683	24	118	1,767	1,529	3,296	1.96	38
P60	2,132	25	118	1,865	1,526	3,391	1.59	25
P70	1,823	26	128	1,887	1,619	3,506	1.92	36
P80	1,898	27	134	1,951	1,668	3,619	1.91	36
P90	2,451	29	136	2,096	1,688	3,784	1.54	24
Max	6,961	57	225	3,772	2,507	6,279	0.90	3
KURT	19.7	9.7	2.9	9.7	2.9	6.5	0.4	0.4
SKEW	3.3	1.5	0.4	1.5	0.4	1.0	-0.8	-0.8
Q1	1,566	21	101	1,620	1,369	3,010	1.56	24
Q3	2,151	26	129	1,916	1,623	3,552	1.92	36
IQR	585	5	28	296	254	542	0.37	12

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 11: Energy use profile: DA 48 06 1168 [Forest Lawn]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	97	97	97	97	97	97	97	97
Mean	1,528	20	94	1,519	1,304	2,823	1.94	37
STDEV	521	5	27	326	247	571	0.33	11
Min	710	10	46	946	862	1,808	2.55	57
P10	864	12	61	1,065	999	2,063	2.39	52
P20	1,430	14	66	1,202	1,048	2,251	1.57	25
P30	1,180	17	76	1,357	1,142	2,499	2.12	43
P40	1,821	18	84	1,443	1,215	2,657	1.46	21
P50	1,373	19	97	1,501	1,328	2,829	2.06	41
P60	1,493	21	105	1,604	1,406	3,010	2.02	39
P70	1,610	23	113	1,704	1,481	3,186	1.98	38
P80	1,733	24	122	1,810	1,561	3,371	1.95	37
P90	1,850	26	130	1,910	1,637	3,547	1.92	36
Max	4,270	37	170	2,585	2,002	4,587	1.07	8
KURT	6.7	0.2	-0.3	0.2	-0.3	0.0	-0.5	-0.5
SKEW	1.4	0.3	0.2	0.3	0.2	0.3	-0.2	-0.2
Q1	1,139	16	73	1,278	1,113	2,409	1.69	29
Q3	1,794	24	115	1,763	1,496	3,239	2.12	43
IQR	655	8	42	485	383	829	0.42	14

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 12: Energy use profile: DA 48 06 1215 [Ogden]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	234	234	234	234	234	234	234	234
Mean	1,658	22	105	1,640	1,409	3,049	1.91	36
STDEV	421	5	24	286	216	500	0.31	10
Min	326	5	23	603	651	1,254	3.85	100
P10	1,042	15	73	1,217	1,114	2,331	2.24	47
P20	1,247	18	88	1,393	1,246	2,640	2.12	43
P30	1,506	22	98	1,643	1,336	2,980	1.98	38
P40	2,239	23	104	1,699	1,393	3,092	1.38	18
P50	1,608	23	113	1,703	1,480	3,183	1.98	38
P60	1,651	23	116	1,740	1,508	3,247	1.97	38
P70	1,705	24	120	1,786	1,543	3,329	1.95	37
P80	1,785	25	126	1,854	1,595	3,449	1.93	37
P90	1,831	26	129	1,894	1,624	3,518	1.92	36
Max	2,929	35	162	2,441	1,932	4,373	1.49	22
KURT	1.4	1.4	0.7	1.4	0.7	1.1	6.5	6.5
SKEW	-0.2	-1.0	-0.9	-1.0	-0.9	-1.0	1.1	1.1
Q1	1,506	20	92	1,518	1,286	2,796	1.74	30
Q3	1,878	25	121	1,829	1,553	3,365	1.99	39
IQR	372	5	29	311	267	570	0.25	8

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 13: Energy use profile: DA 48 06 1636 [Midnapore]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	292	292	292	292	292	292	292	292
Mean	1,604	21	98	1,581	1,345	2,925	1.88	35
STDEV	417	4	21	264	194	456	0.27	9
Min	1,261	13	58	1,099	977	2,075	1.65	27
P10	1,056	15	74	1,229	1,123	2,352	2.23	46
P20	1,121	16	79	1,285	1,165	2,450	2.19	45
P30	1,730	18	80	1,387	1,176	2,563	1.48	22
P40	1,334	19	86	1,492	1,234	2,726	2.04	40
P50	1,479	21	96	1,619	1,320	2,939	1.99	39
P60	1,575	23	102	1,704	1,377	3,081	1.96	37
P70	1,601	23	113	1,697	1,475	3,172	1.98	38
P80	2,062	25	114	1,815	1,490	3,305	1.60	26
P90	1,872	26	132	1,929	1,651	3,580	1.91	36
Max	2,929	33	153	2,322	1,850	4,172	1.42	20
KURT	0.4	-0.7	-0.7	-0.7	-0.7	-0.7	-1.2	-1.2
SKEW	0.7	0.3	0.4	0.3	0.4	0.3	-0.4	-0.4
Q1	1,280	17	80	1,339	1,172	2,482	1.56	24
Q3	1,890	24	112	1,782	1,471	3,247	2.08	42
IQR	611	7	33	443	299	764	0.52	17

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 14: Energy use profile: DA 48 06 1674 [Castleridge]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	163	163	163	163	163	163	163	163
Mean	1,823	22	106	1,684	1,419	3,103	1.76	31
STDEV	465	5	23	285	215	496	0.26	9
Min	867	12	61	1,067	1,001	2,068	2.39	52
P10	1,225	15	68	1,209	1,064	2,273	1.86	34
P20	2,046	20	78	1,544	1,159	2,703	1.32	16
P30	1,362	19	96	1,492	1,321	2,813	2.07	41
P40	1,849	22	102	1,661	1,382	3,042	1.65	27
P50	1,959	23	109	1,740	1,438	3,178	1.62	26
P60	1,673	24	118	1,758	1,522	3,280	1.96	38
P70	1,768	25	124	1,840	1,584	3,423	1.94	37
P80	2,235	27	124	1,940	1,578	3,518	1.57	25
P90	1,916	27	135	1,967	1,679	3,646	1.90	36
Max	2,451	35	172	2,426	2,025	4,451	1.82	33
KURT	0.6	-0.3	-0.5	-0.3	-0.5	-0.4	0.4	0.4
SKEW	0.5	-0.3	-0.3	-0.3	-0.3	-0.3	-0.1	-0.1
Q1	1,567	19	90	1,487	1,266	2,756	1.57	25
Q3	2,080	26	124	1,903	1,579	3,464	1.93	37
IQR	514	7	34	416	314	708	0.37	12

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 15: Energy use profile: DA 48 06 1793 [Citadel]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	224	224	224	224	224	224	224	224
Mean	2,135	25	113	1,811	1,483	3,294	1.57	25
STDEV	442	5	21	276	196	471	0.18	6
Min	1,574	16	73	1,291	1,110	2,401	1.53	23
P10	1,501	18	83	1,409	1,204	2,613	1.74	30
P20	1,682	20	93	1,540	1,296	2,836	1.69	29
P30	1,574	23	102	1,703	1,377	3,079	1.96	37
P40	1,948	23	108	1,732	1,432	3,164	1.62	26
P50	2,086	25	116	1,832	1,502	3,334	1.60	26
P60	2,165	26	120	1,889	1,543	3,432	1.59	25
P70	2,245	27	124	1,947	1,583	3,530	1.57	25
P80	2,589	29	136	2,090	1,686	3,776	1.46	21
P90	2,594	31	144	2,199	1,761	3,960	1.53	23
Max	2,898	35	161	2,419	1,916	4,335	1.50	22
KURT	-0.2	-0.8	-0.8	-0.8	-0.8	-0.8	1.9	1.9
SKEW	0.6	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	0.1
Q1	1,786	21	100	1,615	1,361	2,968	1.51	23
Q3	2,461	28	128	2,000	1,621	3,621	1.63	27
IQR	675	6	28	385	260	654	0.12	4

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

Table 16: Energy use profile: DA 48 06 1880 [Aspen Woods]

	Unit living area (sq.ft)	Adjusted electricity use (GJ/unit/year)	Adjusted gas use (GJ/unit/year)	Electricity bill ($/unit/year)	Gas bill ($/unit/year)	Energy bill ($/unit/year)	Energy bill ($/sq.ft/year)	Normalized (1-100) energy bill - sample
Units	387	387	387	387	387	387	387	387
Mean	4,572	41	178	2,836	2,075	4,911	1.11	9
STDEV	1,397	11	47	662	429	1,070	0.17	6
Min	1,940	22	102	1,648	1,374	3,021	1.56	24
P10	2,436	29	135	2,085	1,681	3,766	1.55	24
P20	3,758	33	150	2,314	1,815	4,129	1.10	9
P30	3,797	33	151	2,335	1,829	4,164	1.10	9
P40	4,634	38	150	2,619	1,816	4,435	0.96	4
P50	4,457	39	177	2,684	2,071	4,755	1.07	8
P60	4,468	44	171	2,989	2,011	4,999	1.12	10
P70	5,625	46	182	3,110	2,110	5,220	0.93	3
P80	4,238	48	222	3,216	2,480	5,695	1.34	17
P90	6,998	57	226	3,790	2,518	6,308	0.90	3
Max	12,400	101	400	6,466	4,122	10,588	0.85	1
KURT	4.4	3.8	2.1	3.8	2.1	3.2	-0.3	-0.3
SKEW	1.5	1.5	1.0	1.5	1.0	1.3	0.8	0.8
Q1	3,506	33	150	2,316	1,820	4,137	0.98	5
Q3	5,213	47	198	3,199	2,258	5,441	1.28	15
IQR	1,707	15	48	882	437	1,304	0.29	10

Note: The normalized score is based on the energy bill per unit of living area ($ per ft2 per year) for the full sample of 12 DAs; the values in column 7 and column 8 correspond to the min, max and percentile values for the total energy bill ($ per unit per year) in column 6; e.g., the 50P values in column 7 and 8 are based on the 50P energy bill in column 6.

9 APPENDIX B: CASE STUDY RESULTS

Table 17: Estimated energy poverty headcount and depth by indicator: DA 48 06 0091 [Highland Park]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	20	20	30	45
% of total households	8%	8%	12%	18%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	60	45	80	80
% of total households	24%	18%	31%	31%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	90	60	90	110
% of total households	35%	24%	35%	43%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	110	80	110	110
% of total households	43%	31%	43%	43%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	80	80	80	90
% of total households	31%	31%	31%	35%
MIS [based on adj., equival. MBM]				
No. of households energy poor	80	60	80	80
% of total households	31%	24%	31%	31%
Energy poverty gap - total	$674,932	$710,524	$714,114	$749,090
Energy poverty gap - average	$8,437	$11,842	$8,926	$9,364
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	30	0	90	90
% of total households	12%	0%	35%	35%
Energy poverty gap - total	$509	$0	$13,475	$49,630
Energy poverty gap - average	$17	$0	$150	$551
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	80	60	80	80
% of total households	31%	24%	31%	31%
Energy poverty gap	$803,384	$790,508	$839,386	$871,524
Energy poverty gap - average	$10,042	$13,175	$10,492	$10,894
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	50	60	80	80
% of total households	20%	24%	31%	31%
Unit energy poverty gap - total	$19,627	$77,020	$67,564	$59,163
Unit energy poverty gap - average	$393	$1,284	$845	$740

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 18: Estimated energy poverty headcount and depth by indicator: DA 48 06 0312 [Varsity]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	0	0	0	0
% of total households	0%	0%	0%	0%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	0	0	5	5
% of total households	0%	0%	4%	4%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	5	5	15	25
% of total households	4%	4%	11%	18%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	5	5	15	25
% of total households	4%	4%	11%	18%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	5	5	5	5
% of total households	4%	4%	4%	4%
MIS [based on adj., equival. MBM]				
No. of households energy poor	5	5	5	5
% of total households	4%	4%	4%	4%
Energy poverty gap - total	$546	$1,557	$3,440	$6,213
Energy poverty gap - average	$109	$311	$688	$1,243
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	5	5	5	5
% of total households	4%	4%	4%	4%
Energy poverty gap - total	$337	$1,347	$3,230	$6,001
Energy poverty gap - average	$67	$269	$646	$1,200
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	5	5	5	5
% of total households	4%	4%	4%	4%
Energy poverty gap	$542	$1,552	$3,435	$6,207
Energy poverty gap - average	$108	$310	$687	$1,241
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	5	5	5	5
% of total households	4%	4%	4%	4%
Unit energy poverty gap - total	$2,411	$5,611	$3,610	$3,161
Unit energy poverty gap - average	$482	$1,122	$722	$632

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 19: Estimated energy poverty headcount and depth by indicator: DA 48 06 0672 [Richmond]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	5	5	10	15
% of total households	2%	2%	4%	6%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	15	15	30	35
% of total households	6%	6%	12%	14%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	30	30	35	60
% of total households	12%	12%	14%	24%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	35	35	60	75
% of total households	14%	14%	24%	30%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	35	35	35	35
% of total households	14%	14%	14%	14%
MIS [based on adj., equival. MBM]				
No. of households energy poor	30	30	30	30
% of total households	12%	12%	12%	12%
Energy poverty gap - total	$201,590	$209,972	$228,401	$245,277
Energy poverty gap - average	$6,720	$6,999	$7,613	$8,176
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	0	0	35	35
% of total households	0%	0%	14%	14%
Energy poverty gap - total	$0	$0	$9,133	$27,583
Energy poverty gap - average	$0	$0	$261	$788
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	30	30	30	30
% of total households	12%	12%	12%	12%
Energy poverty gap	$240,330	$248,185	$265,454	$281,269
Energy poverty gap - average	$8,011	$8,273	$8,848	$9,376
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	10	30	30	30
% of total households	4%	12%	12%	12%
Unit energy poverty gap - total	$2,228	$38,459	$24,740	$21,664
Unit energy poverty gap - average	$223	$1,282	$825	$722

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 20: Estimated energy poverty headcount and depth by indicator: DA 48 06 0777 [Oakridge]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	15	15	15	15
% of total households	11%	11%	11%	11%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	25	15	35	40
% of total households	18%	11%	25%	29%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	40	25	40	50
% of total households	29%	18%	29%	36%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	40	40	50	50
% of total households	29%	29%	36%	36%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	40	40	40	40
% of total households	29%	29%	29%	29%
MIS [based on adj., equival. MBM]				
No. of households energy poor	35	25	35	35
% of total households	25%	18%	25%	25%
Energy poverty gap - total	$400,435	$404,774	$420,691	$433,775
Energy poverty gap - average	$11,441	$16,191	$12,020	$12,394
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	15	0	40	40
% of total households	11%	0%	29%	29%
Energy poverty gap - total	$792	$0	$16,040	$30,656
Energy poverty gap - average	$53	$0	$401	$766
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	35	25	35	35
% of total households	25%	18%	25%	25%
Energy poverty gap	$411,782	$410,580	$431,583	$444,373
Energy poverty gap - average	$11,765	$16,423	$12,331	$12,696
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	35	25	35	35
% of total households	25%	18%	25%	25%
Unit energy poverty gap - total	$26,289	$21,908	$20,557	$18,001
Unit energy poverty gap - average	$751	$876	$587	$514

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 21: Estimated energy poverty headcount and depth by indicator: DA 48 06 0956 [Whitehorn]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	10	10	15	15
% of total households	5%	5%	8%	8%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	15	15	30	35
% of total households	8%	8%	15%	18%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	35	35	35	60
% of total households	18%	18%	18%	30%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	60	35	60	60
% of total households	30%	18%	30%	30%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	60	60	60	60
% of total households	30%	30%	30%	30%
MIS [based on adj., equival. MBM]				
No. of households energy poor	30	30	30	30
% of total households	15%	15%	15%	15%
Energy poverty gap - total	$344,879	$348,086	$356,465	$363,355
Energy poverty gap - average	$11,496	$11,603	$11,882	$12,112
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	30	30	30	30
% of total households	15%	15%	15%	15%
Energy poverty gap - total	$16,545	$20,367	$30,352	$38,563
Energy poverty gap - average	$552	$679	$1,012	$1,285
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	30	30	30	30
% of total households	15%	15%	15%	15%
Energy poverty gap	$290,985	$294,807	$304,792	$313,003
Energy poverty gap - average	$9,700	$9,827	$10,160	$10,433
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	30	30	30	30
% of total households	15%	15%	15%	15%
Unit energy poverty gap - total	$7,144	$37,716	$24,263	$21,246
Unit energy poverty gap - average	$238	$1,257	$809	$708

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 22: Estimated energy poverty headcount and depth by indicator: DA 48 06 1091 [Castleridge]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	0	5	15	20
% of total households	0%	3%	9%	13%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	15	15	20	25
% of total households	9%	9%	13%	16%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	40	20	25	35
% of total households	25%	13%	16%	22%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	45	20	35	50
% of total households	28%	13%	22%	31%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	35	35	35	35
% of total households	22%	22%	22%	22%
MIS [based on adj., equival. MBM]				
No. of households energy poor	20	20	20	20
% of total households	13%	13%	13%	13%
Energy poverty gap - total	$242,896	$244,276	$257,631	$265,829
Energy poverty gap - average	$12,145	$12,214	$12,882	$13,291
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	15	20	20	20
% of total households	9%	13%	13%	13%
Energy poverty gap - total	$2,367	$3,596	$19,510	$29,279
Energy poverty gap - average	$158	$180	$975	$1,464
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	20	20	20	20
% of total households	13%	13%	13%	13%
Energy poverty gap	$208,114	$209,759	$225,673	$235,442
Energy poverty gap - average	$10,406	$10,488	$11,284	$11,772
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	20	20	20	20
% of total households	13%	13%	13%	13%
Unit energy poverty gap - total	$7,701	$19,406	$12,484	$10,932
Unit energy poverty gap - average	$385	$970	$624	$547

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 23: Estimated energy poverty headcount and depth by indicator: DA 48 06 1168 [Forest Lawn]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	45	25	50	55
% of total households	28%	16%	31%	34%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	65	50	65	70
% of total households	41%	31%	41%	44%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	70	55	70	100
% of total households	44%	34%	44%	63%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	100	65	80	100
% of total households	63%	41%	50%	63%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	70	70	70	80
% of total households	44%	44%	44%	50%
MIS [based on adj., equival. MBM]				
No. of households energy poor	70	65	70	70
% of total households	44%	41%	44%	44%
Energy poverty gap - total	$1,162,804	$1,154,732	$1,197,642	$1,252,316
Energy poverty gap - average	$16,611	$17,765	$17,109	$17,890
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	0	0	0	80
% of total households	0%	0%	0%	50%
Energy poverty gap - total	$0	$0	$0	$43,032
Energy poverty gap - average	$0	$0	$0	$538
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	70	65	70	70
% of total households	44%	41%	44%	44%
Energy poverty gap	$1,229,369	$1,210,556	$1,261,381	$1,311,618
Energy poverty gap - average	$17,562	$18,624	$18,020	$18,737
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	60	65	70	70
% of total households	38%	41%	44%	44%
Unit energy poverty gap - total	$33,821	$57,251	$40,646	$35,592
Unit energy poverty gap - average	$564	$881	$581	$508

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 24: Estimated energy poverty headcount and depth by indicator: DA 48 06 1215 [Ogden]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	5	20	30	40
% of total households	2%	7%	11%	15%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	40	40	65	65
% of total households	15%	15%	24%	24%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	75	50	75	95
% of total households	28%	19%	28%	35%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	75	65	95	95
% of total households	28%	24%	35%	35%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	75	75	75	75
% of total households	28%	28%	28%	28%
MIS [based on adj., equival. MBM]				
No. of households energy poor	65	50	65	65
% of total households	24%	19%	24%	24%
Energy poverty gap - total	$627,555	$649,786	$684,873	$707,670
Energy poverty gap - average	$9,655	$12,996	$10,537	$10,887
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	10	0	75	75
% of total households	4%	0%	28%	28%
Energy poverty gap - total	$215	$0	$21,947	$47,111
Energy poverty gap - average	$22	$0	$293	$628
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	65	50	65	65
% of total households	24%	19%	24%	24%
Energy poverty gap	$675,216	$679,896	$730,048	$751,857
Energy poverty gap - average	$10,388	$13,598	$11,232	$11,567
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	65	50	65	65
% of total households	24%	19%	24%	24%
Unit energy poverty gap - total	$48,659	$34,710	$31,750	$27,803
Unit energy poverty gap - average	$749	$694	$488	$428

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 25: Estimated energy poverty headcount and depth by indicator: DA 48 06 1636 [Midnapore]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	0	10	20	25
% of total households	0%	3%	6%	8%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	25	25	30	55
% of total households	8%	8%	10%	18%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	30	30	55	80
% of total households	10%	10%	18%	26%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	40	40	55	80
% of total households	13%	13%	18%	26%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	55	55	55	55
% of total households	18%	18%	18%	18%
MIS [based on adj., equival. MBM]				
No. of households energy poor	40	40	40	40
% of total households	13%	13%	13%	13%
Energy poverty gap - total	$355,861	$358,960	$382,977	$409,199
Energy poverty gap - average	$8,897	$8,974	$9,574	$10,230
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	0	0	55	55
% of total households	0%	0%	18%	18%
Energy poverty gap - total	$0	$0	$6,090	$41,333
Energy poverty gap - average	$0	$0	$111	$752
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	40	40	40	40
% of total households	13%	13%	13%	13%
Energy poverty gap	$370,855	$373,884	$397,361	$422,993
Energy poverty gap - average	$9,271	$9,347	$9,934	$10,575
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	40	40	40	40
% of total households	13%	13%	13%	13%
Unit energy poverty gap - total	$23,076	$32,455	$20,878	$18,282
Unit energy poverty gap - average	$577	$811	$522	$457

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 26: Estimated energy poverty headcount and depth by indicator: DA 48 06 1674 [Castleridge]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	0	0	0	0
% of total households	0%	0%	0%	0%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	0	0	10	20
% of total households	0%	0%	6%	12%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	0	0	20	30
% of total households	0%	0%	12%	18%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	5	10	30	30
% of total households	3%	6%	18%	18%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	30	30	30	30
% of total households	18%	18%	18%	18%
MIS [based on adj., equival. MBM]				
No. of households energy poor	10	10	10	10
% of total households	6%	6%	6%	6%
Energy poverty gap - total	$56,437	$57,310	$64,302	$67,923
Energy poverty gap - average	$5,644	$5,731	$6,430	$6,792
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	5	10	10	10
% of total households	3%	6%	6%	6%
Energy poverty gap - total	$269	$1,359	$10,405	$15,090
Energy poverty gap - average	$54	$136	$1,041	$1,509
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	5	10	10	10
% of total households	3%	6%	6%	6%
Energy poverty gap	$21,103	$23,719	$32,764	$37,449
Energy poverty gap - average	$4,221	$2,372	$3,276	$3,745
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	10	10	10	10
% of total households	6%	6%	6%	6%
Unit energy poverty gap - total	$6,034	$7,432	$4,781	$4,187
Unit energy poverty gap - average	$603	$743	$478	$419

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 27: Estimated energy poverty headcount and depth by indicator: DA 48 06 1793 [Citadel]

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	0	0	0	5
% of total households	0%	0%	0%	2%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	0	0	15	20
% of total households	0%	0%	7%	9%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	5	15	20	50
% of total households	2%	7%	9%	23%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	20	20	35	50
% of total households	9%	9%	16%	23%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	20	20	20	20
% of total households	9%	9%	9%	9%
MIS [based on adj., equival. MBM]				
No. of households energy poor	15	15	15	15
% of total households	7%	7%	7%	7%
Energy poverty gap - total	$49,859	$51,209	$61,027	$69,552
Energy poverty gap - average	$3,324	$3,414	$4,068	$4,637
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	10	15	20	20
% of total households	5%	7%	9%	9%
Energy poverty gap - total	$395	$1,549	$15,443	$27,964
Energy poverty gap - average	$40	$103	$772	$1,398
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	15	15	15	15
% of total households	7%	7%	7%	7%
Energy poverty gap	$23,593	$25,080	$35,895	$45,286
Energy poverty gap - average	$1,573	$1,672	$2,393	$3,019
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	15	15	15	15
% of total households	7%	7%	7%	7%
Unit energy poverty gap - total	$2,846	$16,645	$10,707	$9,376
Unit energy poverty gap - average	$190	$1,110	$714	$625

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

Table 28: Estimated energy poverty headcount and depth by indicator: DA 48 06 1880 [Aspen Woods

Indicator [specification of criteria]	Best est.	10 P	50 P	90 P
Energy cost / income ratio [=10%, AT-income BHC]				
No. of households energy poor	5	10	20	25
% of total households	1%	3%	5%	6%
Energy cost / income ratio [=10%, AT-income AHC]				
No. of households energy poor	15	20	25	45
% of total households	4%	5%	6%	12%
2M [sample = 6.1%, AT-income BHC]				
No. of households energy poor	25	25	45	65
% of total households	6%	6%	12%	17%
2M [sample = 7.2%, AT-income AHC]				
No. of households energy poor	25	35	45	65
% of total households	6%	9%	12%	17%
After energy cost poverty [AT-LICO poverty line]				
No. of households energy poor	20	25	25	25
% of total households	5%	6%	6%	6%
MIS [based on adj., equival. MBM]				
No. of households energy poor	15	15	15	15
% of total households	4%	4%	4%	4%
Energy poverty gap - total	$207,269	$214,326	$227,117	$247,196
Energy poverty gap - average	$13,818	$14,288	$15,141	$16,480
LIHC [equiv. P30 energy cost for sample & LICO-AT for YYC]				
No. of households energy poor	15	15	20	20
% of total households	4%	4%	5%	5%
Energy poverty gap - total	$12,552	$20,741	$37,266	$68,330
Energy poverty gap - average	$837	$1,383	$1,863	$3,416
MIS [adj., equival. MBM] & 2M [7.2%, AT-income AHC]				
No. of households energy poor	15	15	15	15
% of total households	4%	4%	4%	4%
Energy poverty gap	$187,378	$195,567	$210,408	$233,706
Energy poverty gap - average	$12,492	$13,038	$14,027	$15,580
LILEE [MIS as above & P50 unit energy costs for sample]				
No. of households energy poor	15	15	15	15
% of total households	4%	4%	4%	4%
Unit energy poverty gap - total	$1,225	$22,471	$14,455	$12,658
Unit energy poverty gap - average	$82	$1,498	$964	$844

Note: 10P, 50P and 90P values correspond to annual energy (unit) costs in Appendix A

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