



Peoples Energy Analytics

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Defining Energy Affordability

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In my feedback to the IRWG on the Near-Term Rate Strategy Report, I recommended that the work should include a clear definition of energy affordability. I developed the definition presented here to support the work of the Massachusetts Interagency Rates Working Group (IRWG) in their consideration of near- and long-term electricity rates that support decarbonization. In this report I detail a proposed framework for a comprehensive definition of energy affordability. I then enumerate the components that contribute to it, and the data sources, data challenges, and data needs for each component.

Definition

Energy affordability ensures that households can access the energy they need to maintain comfortable living conditions, participate in modern society, and manage energy costs without facing energy poverty or undue financial strain.⁸⁹ This means having access to enough reliable, clean energy to meet essential needs such as heating, cooling, lighting, cooking, and powering appliances, while still having sufficient financial resources to cover other living expenses.⁹⁰ Energy affordability

⁸⁹ Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., & Cox, M. (2020). High energy burden and low-income energy affordability: conclusions from a literature review. *Progress in Energy*, 2(4), 042003; Scheier, E., & Kittner, N. (2022). A measurement strategy to address disparities across household energy burdens. *Nature Communications*, 13(1), 288; Heindl, P., & Schüssler, R. (2015). Dynamic properties of energy affordability measures. *Energy Policy*, 86, 123-132; Cong, S., Ku, A. L., Nock, D., Ng, C., & Qiu, Y. L. (2024). Comfort or cash? Lessons from the COVID-19 pandemic's impact on energy insecurity and energy limiting behavior in households. *Energy Research & Social Science*, 113, 103528.

⁹⁰ Welsch, H., & Biermann, P. (2017). Energy affordability and subjective well-being: Evidence for European countries. *The Energy Journal*, 38(3), 159-176; Also, see the United Nations Sustainable Development Goal 7. <https://sdgs.un.org/goals/goal7>



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also necessitates a balanced approach, where the cost of energy is reasonable relative to household income and individual circumstances, preventing individuals from having to choose between paying for energy and other basic needs like food, healthcare, or housing.⁹¹ Conversely, energy is not affordable if the cost of energy influences an individual's ability to heat and cool their home to avoid adverse health risks.

Energy affordability encompasses an ecosystem of factors, including: the cost of energy bills, the efficiency of energy end uses, access to modern energy technologies, and the impact of policies and rate structures.⁹² Further, energy affordability is influenced by factors such as rate structures, household income, location, energy-efficient infrastructure, and equitable access to renewable energy solutions.⁹³ One method to measure energy affordability is to calculate the percent of income (energy burden) a household spends to maintain an adequate level of warmth or cooling.⁹⁴ The World Health Organization recommends indoor temperatures of 70°F (21°C) in living rooms and 64°F (18°C) in other occupied rooms during daytime hours.⁹⁵ I note that currently in the U.S. the energy burden

⁹¹ Miniaci, R., Scarpa, C., & Valbonesi, P. (2014). Energy affordability and the benefits system in Italy. *Energy Policy*, 75, 289-300; Carley, S., Graff, M., Konisky, D. M., & Memmott, T. (2022). Behavioral and financial coping strategies among energy-insecure households. *Proceedings of the National Academy of Sciences*, 119(36); Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social science & medicine*, 167, 1-10.

⁹² Hernández, D., & Bird, S. (2010). Energy burden and the need for integrated low-income housing and energy policy. *Poverty & public policy*, 2(4), 5-25.

⁹³ Simcock, N., Jenkins, K. E., Lacey-Barnacle, M., Martiskainen, M., Mattioli, G., & Hopkins, D. (2021). Identifying double energy vulnerability: A systematic and narrative review of groups at-risk of energy and transport poverty in the global north. *Energy Research & Social Science*, 82, 102351.

⁹⁴ In her 1991 book, *Fuel Poverty: From Cold Homes to Affordable Warmth*, Brenda Boardman introduced the concept of fuel poverty, defining it as a household needing to spend more than 10% of its income to maintain adequate warmth. Currently in the U.S. the affordability threshold is often set to 4-6% of income. Citation: Boardman, B. (1991). *Fuel poverty: from cold homes to affordable warmth*.

⁹⁵ The World Health Organization has many recommendations for indoor temperatures. They highlight that cold indoor temperatures are often a consequence of outdoor temperature, structural deficiencies, including



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affordability threshold is often set to 4-10% of income⁹⁶ and that energy burden often does not include a temperature indicator.⁹⁷ Thus, I suggest including energy limiting behavior metrics,⁹⁸ in addition to energy burden, to paint a more holistic measure of energy affordability.

Components of Affordability

Energy affordability encompasses several key components, all of which interrelate to energy bills, energy usage, and the technologies employed to produce and manage energy. Here are the primary components:

1. Energy Costs (Energy Bills)

- **Rate Structures:** The way utilities structure pricing, such as inclining block rates (where higher usage results in higher per-unit costs), time-of-use (TOU) rates (where prices vary based on timing of peak demand), seasonal rates (where bills can be very high in winter or

a lack of insulation and airtightness, and lack of heating. As outlined in this chapter, cold indoor temperatures have been associated with increased blood pressure, asthma symptoms and poor mental health. See <https://www.who.int/publications/i/item/9789241550376>

⁹⁶ Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., & Cox, M. (2020). High energy burden and low-income energy affordability: conclusions from a literature review. *Progress in Energy*, 2(4), 042003; Cook, J. J., & Shah, M. (2018). Reducing energy burden with solar: Colorado's strategy and roadmap for states (No. NREL/TP-6A20-70965). National Renewable Energy Lab. (NREL), Golden, CO (United States).

⁹⁷ In addition to lacking temperature analysis, most energy burden studies do not analyze household spending on transportation energy or water services. In addition, these energy burden studies do not tend to include different sources of financial support. From 2013–2014, household energy burdens were estimated to be 16.3% for low-income households and 3.5% for non-low-income households. Sourced from: Eisenberg, J. F. (2014). Weatherization assistance program technical memorandum background data and statistics on low-income energy use and burdens (No. ORNL/TM-2014/133). Oak Ridge National Lab. (ORNL), Oak Ridge, TN (United States).

⁹⁸ Cong, S., Nock, D., Qiu, Y. L., & Xing, B. (2022). Unveiling hidden energy poverty using the energy equity gap. *Nature communications*, 13(1), 2456; Huang, L., Nock, D., Cong, S., & Qiu, Y. L. (2023). Inequalities across cooling and heating in households: Energy equity gaps. *Energy Policy*, 182, 113748; Cong, S., Nock, D., Laasme, H., Qiu, Y. L., & Xing, B. (2023). Understanding energy limiting behavior in different climate zones: case studies of three utility service regions. <https://www.researchsquare.com/article/rs-3361275/v1>



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summer months and lower in spring and fall months), or fixed rates, can significantly affect affordability.⁹⁹ Rate design, for instance, can disproportionately negatively affect households that use less energy but pay a higher percentage of their income on fixed charges, such as if they are low- or moderate-income, or on a fixed income. Additionally, rate design can also hurt certain vulnerable households if they are higher energy consumers (for instance, due to using resistance heating, having many occupants in the home, and/or having a low-quality housing unit), or if the consumer struggles to adequately manage bill volatility across seasons (e.g., energy bills are higher in winter and summer, than in spring or fall) due to inflexible loads.

- **Energy Poverty Stemming from Financial Strain:** Households are often considered energy poor when they spend a large proportion of their income on energy bills, typically defined as over 6-10% of household income, and when they are under consuming energy to the point where they place themselves at a health risk (i.e., energy limiting behavior or energy insecurity).¹⁰⁰ Therefore, households can be at risk of energy poverty if they have low- or moderate-income, fixed-income, or single-income, or based on usage (such as medical devices, disabilities, or working hours/living situation). Energy poverty is characterized by, for

⁹⁹ Miniaci, R., Scarpa, C., & Valbonesi, P. (2014). Energy affordability and the benefits system in Italy. *Energy Policy*, 75, 289-300.

¹⁰⁰ Brown, M. A., Soni, A., Lapsa, M. V., Southworth, K., & Cox, M. (2020). High energy burden and low-income energy affordability: conclusions from a literature review. *Progress in Energy*, 2(4), 042003.



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instance, an increase in utility disconnections, and a decrease in adequate indoor temperature regulation (i.e., energy limiting behavior),¹⁰¹ causing adverse health risks.¹⁰²

- **Subsidies and Assistance Programs:** Programs like the Low-Income Home Energy Assistance Program (LIHEAP, renamed HEAP in Massachusetts), utility discount rates, or utility bill arrearage management programs can help reduce the burden of energy bills for low-income households.

2. Energy Usage

- **Efficiency of Homes and Appliances:** Older, inefficient appliances or poorly insulated homes can lead to higher energy consumption, inflating energy bills. Increasing energy efficiency through home upgrades (like insulation, efficient lighting, and smart thermostats) can reduce overall usage and increase affordability.

The quality of homes and appliances is heavily influenced by policies. For example, in Massachusetts energy efficiency upgrades (e.g., insulation, smart thermostats, etc.) have been incentivized through Mass Save rebates. In addition to this, strong federal appliance standards have helped ensure the efficiency of energy technologies in the home. Strict state policies regarding building codes have largely reduced the heating load. These efforts have reduced energy usage and lowered energy bills for those that are able to access and adopt

¹⁰¹ For more about energy limiting behavior, see research by Dr. Nock and her company. Research paper 1: Cong, S., Ku, A. L., Nock, D., Ng, C., & Qiu, Y. L. (2024). Comfort or cash? Lessons from the COVID-19 pandemic's impact on energy insecurity and energy limiting behavior in households. *Energy Research & Social Science*, 113, 103528; Research paper 2: Cong, S., Nock, D., Qiu, Y. L., & Xing, B. (2022). Unveiling hidden energy poverty using the energy equity gap. *Nature communications*, 13(1), 2456; Company work is at Peoples Energy Analytics.

¹⁰² Sometimes these energy hardships are referred to as energy insecurity. Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social science & medicine*, 167, 1-10.



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these technologies (e.g., homeowners) but there is still more work to be done in identifying gaps in adoption capabilities (e.g., renter populations and those in older homes).

- **Behavioral Factors:** How individuals use energy (e.g., heating/cooling practices, appliance usage habits) influences consumption. Awareness and education about structural and social barriers to energy-saving behaviors are essential for improving affordability.
- **Individual circumstances:** Energy usage varies by many lifestyle factors, some of which are dictated by circumstances not within an individual's control, making them vulnerable to energy insecurity or poverty, such as having to power medical devices, accommodate disabilities, and having to maintain an indoor temperature regulation necessary to support health and comfort.
- **Energy limiting behavior:** Households are considered to be exhibiting energy limiting behavior when they reduce their energy use to save money on bills, thereby putting themselves at risk of adverse health impacts. For example, this can include turning off working air conditioning and heating systems, being unable to fix a broken heating or cooling equipment, or being unable to purchase cooling equipment.¹⁰³ This can be considered a subset of behavior factors.¹⁰⁴

¹⁰³ Huang, L., Nock, D., Cong, S., & Qiu, Y. L. (2023). Inequalities across cooling and heating in households: Energy equity gaps. *Energy Policy*, 182, 113748; Kwon, M., Cong, S., Nock, D., Huang, L., Qiu, Y. L., & Xing, B. (2023). Forgone summertime comfort as a function of avoided electricity use. *Energy Policy*, 183, 113813. <https://www.sciencedirect.com/science/article/pii/S0301421523003981>.

¹⁰⁴ Cong, S., Ku, A. L., Nock, D., Ng, C., & Qiu, Y. L. (2024). Comfort or cash? Lessons from the COVID-19 pandemic's impact on energy insecurity and energy limiting behavior in households. *Energy Research & Social Science*, 113, 103528. <https://www.sciencedirect.com/science/article/pii/S2214629624001191>.



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- **Demand Side Management (DSM):** Programs that encourage users to shift their usage to off-peak times or reduce consumption during peak times can lower overall energy costs, making energy more affordable for those that are able to participate.

3. Energy Technologies

- **Clean Energy Adoption:** In Massachusetts, there is the ability to take advantage of distributed generation (DG) and net energy metering incentive programs. Technologies like solar panels or wind energy can lower long-term energy costs, especially if paired with battery storage to manage intermittent supply. However, the upfront cost of these technologies can be a barrier for lower- and fixed-income households, and can be inaccessible to renters based on landlord uptake. I note that the Commonwealth has made significant efforts and progress in expanding access via the establishment of a variety of community solar offerings to reach these customers (e.g., renters, low-income and fixed-income) and are continually improving community solar offerings.
- **Electrification and Regenerative Energy Systems:** Shifting to electrified systems (like heat pumps, electric vehicles, and induction stoves) can reduce energy bills. There can be further savings if households also adopt on-site clean energy. Thus, Massachusetts should continue to support policies which reduce or eliminate the upfront cost of electrification appliances for low- and moderate-income households.

4. Policy and Regulation

- **Regulatory Frameworks:** Government policies, such as renewable energy incentives, energy efficiency standards, and carbon pricing, impact the affordability of energy technologies and



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the cost of energy for consumers. Utility regulatory frameworks and business models, such as the regulated rate of return and other incentive structures, also impact the cost of energy and impact the ability and willingness of utilities to address affordability challenges.

- **Data Sharing and Communication:** As discussed in the following section, data regarding the amount of energy households are using by location, heating and cooling systems in a home, income and demographic group, house size, occupant age, and house age could be used to understand affordability challenges across the state. However, responsive policy and regulation enables the creation and sharing of data.
- **Decarbonization Policies:** Efforts to reduce carbon emissions, such as transitioning to clean and renewable energy sources and the other enabling investments, such as the electric grid, can have mixed effects on affordability. While clean energy may be cheaper in the long term, the short-term costs of transitioning from fossil fuels can raise prices unless mitigated by subsidies or policy support.
- **Equity in Energy Transition:** Ensuring that vulnerable populations, such as lower- and fixed-income households or marginalized communities, benefit from energy transitions is essential for affordability. Without equitable access to efficiency upgrades, and improvements in the housing quality, these groups may face higher costs while others benefit from lower bills. In addition, there is concern that low-income households will be some of the last to completely electrify and phase out of the gas network. As less customers are on the natural gas network the costs of maintaining that system will be high, and thus, the electricity sector may need to supplement the final phase out of fossil fuels.



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5. Local Factors

- **Geography and Infrastructure:** Energy costs vary by region due to differences in energy sources, weather patterns (which affect heating/cooling needs), and infrastructure. Remote or underserved areas may face higher energy costs due to limited access to clean, affordable energy technologies or reliance on more expensive fuel types.
- **Climate:** In colder or hotter climates, energy usage for heating and cooling is a significant component of energy bills. Efficient systems can lower costs, but the investment in those systems can be a barrier to affordability.

These components highlight the complex relationship between energy usage, technologies, and affordability, particularly for lower-income households and other vulnerable populations. Programs that combine energy efficiency, clean energy adoption, and policy support can help mitigate energy costs while promoting equitable energy use. The following figure summarizes the ecosystem of components contributing to energy affordability.

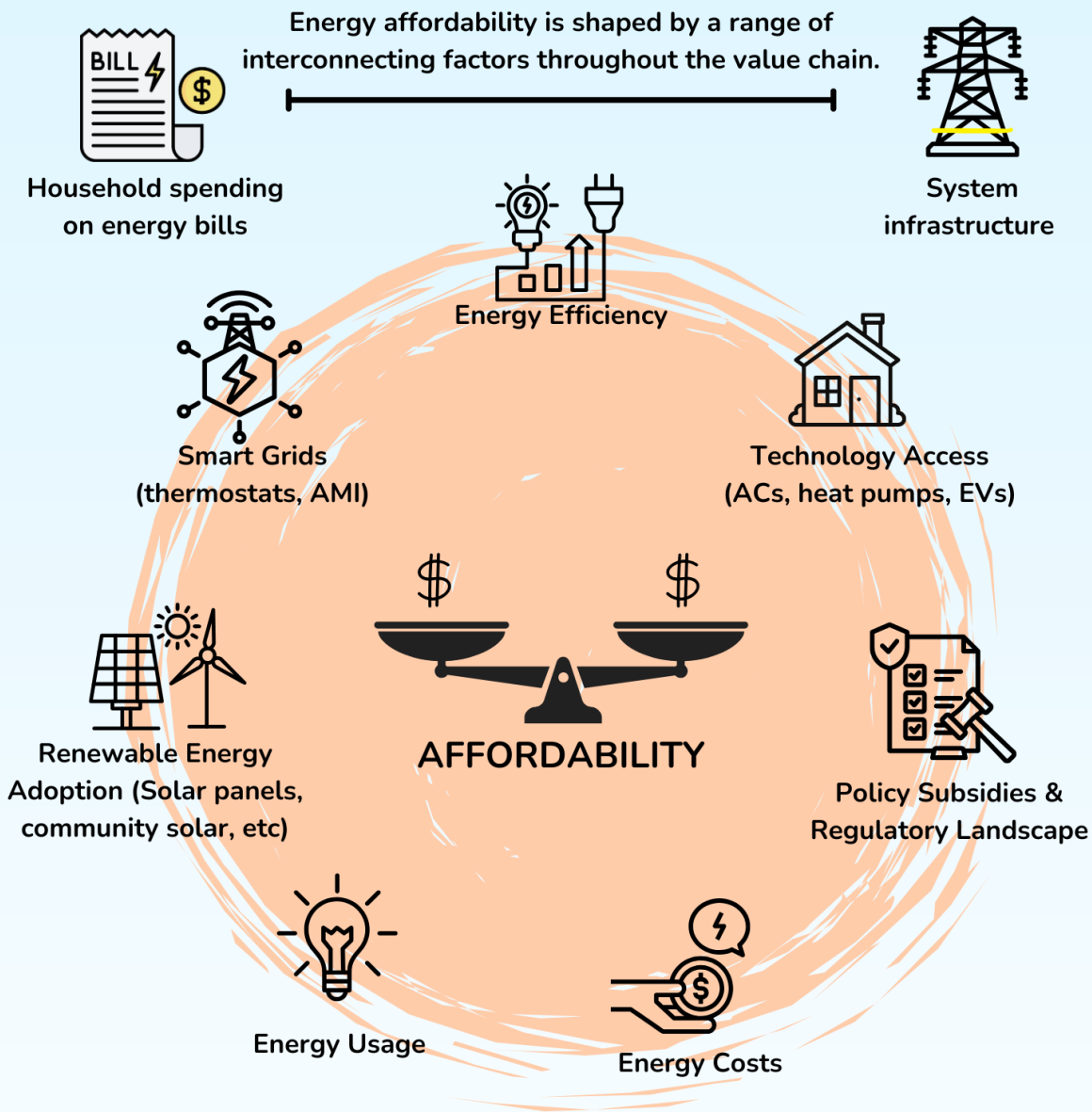


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ENERGY AFFORDABILITY



Local Factors:



Weather



Climate



Infrastructure



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Data Sources, Needs, and Challenges

Addressing energy affordability requires collecting, analyzing, and managing various types of data from multiple sources. Each component of energy affordability presents unique data needs and challenges. Below is a breakdown of the key data sources, data needs, and data challenges for each of the components. This data should be used to create a model of energy risks for each individual household, and to identify energy affordability challenges across a utility's territory in real time. This model would be used for an in-depth system analysis which would then allow regions, regulators, utilities, and community advocates to understand how the energy system, or changes to the system impacts individuals. The measured impacts should include energy bill spending relative to other household expenses (i.e., energy burden adjusted for cost of living),¹⁰⁵ thermal comfort and safety (i.e., energy limiting behavior), as well as infrastructure deficits and needs.

1. Energy Costs (Energy Bills)

Data Sources:

- **Utility Bills:** Monthly or annual billing data from energy providers and utilities.
- **Rate Structures:** Public records from utilities or government agencies on pricing mechanisms (e.g., tiered rates, time-of-use rates).
- **Census and Economic Data:** Information on household income and demographics (e.g., U.S. Census Bureau, Eurostat).

¹⁰⁵ Zhang, J., Nock, D., & Li, X. (2024). Ignoring cost of living misses the true level of energy burden.



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- **Subsidy and Assistance Program Data:** LIHEAP data, utility discount programs, or energy subsidies information.

Data Needs:

- Accurate data on household energy consumption and costs over time.
- Information on energy pricing structures and how they vary by region and customer class.
- Household income levels to measure energy burden (i.e., the percentage of income spent on energy).

Data Challenges:

- **Multiple sources of energy use:** Electricity bills do not encompass all energy costs, which is increasingly true as end uses such as transportation electrify. Access to bill data for all energy uses would increase accuracy and understanding, such as the cost of delivered fuels and transportation fuels.
- **Privacy Concerns:** Access to individual household energy bills and income data may be restricted due to privacy protections.
- **Inconsistent Reporting:** Energy bills may be reported differently across utilities, making it hard to compare data.
- **Hidden Costs:** Fees, taxes, or other charges on energy bills may vary, obscuring actual costs.



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2. Energy Usage

Data Sources:

- **Meters:** Ideally real-time data from utilities on energy consumption at the daily, hourly, or sub-hourly timescale. If AMI has not been deployed, then monthly meter data can be used.
- **Surveys and Household Energy Audits:** Surveys on appliances, insulation, heating/cooling systems, and behavior (e.g., Residential Energy Consumption Survey).
- **Building Codes, Characteristics, and Standards:** Data on building materials, insulation, age, size, location, energy efficiency codes, and other building characteristics.

Data Needs:

- Real-time or near-real-time energy consumption data at the household and appliance level. The ideal time step is energy usage at the daily or sub-hourly timescale. If AMI has not been deployed, then monthly meter data can be used.
- Data on energy efficiency of buildings, appliances, and HVAC systems.
- Behavioral data on how households use energy and make decisions about the use of energy.

Data Challenges:

- **Access to Meter Data:** Utility companies may not share detailed consumption data due to privacy concerns.
- **Self-Reported Data:** Surveys may rely on self-reported information, which can be inaccurate or incomplete.



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- **Granularity:** Getting detailed, appliance-level usage data can be difficult and costly. To overcome this hurdle load disaggregation devices and software can be used.

3. Energy Technologies

Data Sources:

- **Clean and Renewable Energy Installations:** Data on solar panels, wind turbines, and battery storage systems (e.g., National Renewable Energy Laboratory databases) at the household and community level. (i.e., utility scale).
- **Smart Grid Infrastructure:** Data from utility companies on grid modernization systems and device deployments, and grid capabilities.
- **Energy Performance Data:** Manufacturer and third-party performance reports on energy-efficient appliances and systems.

Data Needs:

- Data on the cost, performance, environmental impacts, and lifespan of clean energy systems and energy-efficient appliances.
- Adoption rates and distribution of renewable energy technologies across different income groups and geographies. This would include which homes have installed this technology behind the meter, and which community scale projects have been established.
- Data on incentives or subsidies for energy technologies.

Data Challenges:

- **Upfront Costs:** Data on actual installation and maintenance costs can be difficult to obtain.



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- **Equitable Access:** Gathering data on how technology adoption varies across socio-economic groups and regions.
- **Technology Integration:** Data on how new technologies integrate with existing energy systems and the challenges of scaling these technologies.

4. Policy and Regulation

Data Sources:

- **Government Energy Reports:** Regulatory filings, government databases, and energy commission reports (e.g., Department of Energy, Federal Energy Regulatory Commission).
- **Utility and Policy Databases:** e.g., DSIRE (Database of State Incentives for Renewables & Efficiency), state public utility commission records.
- **Energy Poverty and Assistance Program Data:** Data from agencies managing energy assistance programs (e.g., LIHEAP and WAP).

Data Needs:

- Comprehensive data on energy policies, subsidies, and assistance programs at local, state, tribal, and federal levels.
- Data on the impact of regulatory changes on energy prices and affordability.
- Information on policy-driven technology adoption (e.g., subsidies for solar panels or energy efficiency upgrades).



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Data Challenges:

- **Timeliness:** Policies change frequently, and there can be a delay in the availability of up-to-date data.
- **Quantifying Impact:** Measuring the direct impact of policies on household affordability is complex and often indirect.

5. Local Factors (Geography, Climate, Infrastructure)

Data Sources:

- **Weather and Climate Data:** Data on temperature patterns, heating degree days, cooling degree days (e.g., NOAA, local weather stations).
- **Geospatial Data:** Geographic Information Systems (GIS) data on energy infrastructure, remote or underserved areas, and access to different energy technologies like solar panels, EV charging infrastructure. Data sources can include satellite data, and local surveys.
- **Census and Demographic Data:** Information on population density, household composition, and regional economic data (e.g., U.S. Census Bureau).

Data Needs:

- Regional data on energy demand influenced by weather (heating/cooling needs) and infrastructure (housing quality/age, insulation, grid reliability, renewable sources). This is partially addressed by E3's HEEM analysis (which uses ResStock),¹⁰⁶ and can be enhanced by benchmarking against utility data, once it becomes available.

¹⁰⁶ HEEM stands for Household Energy Expenditure Model. See E3's Near-Term Rate Strategy Report.



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- Data on regional fuel types and energy costs.
- Local data on building efficiency and the adoption of energy-efficient technologies by census track. Ideally the adoption of energy efficiency appliances would be captured at the building/household level so it can be paired with energy usage data from energy utilities. In the absence of available building data, this can be modeled with trends and averages using models like NREL's ResStock.

Data Challenges:

- **Regional Disparities:** Energy usage and needs vary significantly across geographic locations, making data comparison challenging.
- **Weather Volatility:** Unpredictable weather events can make energy needs fluctuate dramatically.
- **Infrastructure Limitations:** Data on energy infrastructure in rural or underserved areas may be incomplete or outdated. Energy infrastructure can include availability of high-quality internet in the area (necessary for interacting with smart thermostats, participating in demand response, and some distributed generation technologies).

Overall Data Challenges Across All Components:

- **Data Silos:** Many data sources (utility, demographic, technology, policy) are siloed and not easily integrated, which limits the ability to assess affordability holistically.
- **Privacy and Accessibility:** Individual household data on energy usage and income is often private and accessing detailed consumption data can be restricted by utilities or regulators.



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- **Data Granularity:** Many datasets lack the granularity needed to provide actionable insights at a household level, such as specific energy use behaviors, appliance performance, or the precise impact of subsidies.
- **Data Collection Costs:** Collecting detailed, real-time data on energy usage and technology adoption is expensive and resource intensive.

Conclusion

By addressing these data needs and overcoming the associated challenges, researchers and policymakers can better understand and improve energy affordability, especially for vulnerable populations. My objective with highlighting all of the data needs and challenges is not to say that this effort is insurmountable, but rather, that affordability is multidimensional and complex. There are multiple opportunities for improving affordability efforts in the region, and here the goal is to highlight the opportunities to use data to spur progress towards energy affordability goals. By knowing the challenges, goals, and data opportunities the region can better design the solutions needed to ensure energy is affordable for every household.



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