Shining a light on the just path forward

JUST SOLUTIONS

Building Efficiency Standards Are Foundational for Broad-Based Community Resilience

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Building efficiency standards are the foundation for resilience, equity, and sustainability in the face of climate extremes and power outages.

- **> Enhances Resilience**
  During extreme weather and prolonged power outages.
- **> Improves Passive Survivability**
  By maintaining livable indoor temperatures without space heating or cooling.
- **> Reduces Energy Costs**
  For homeowners and renters, making housing thermal efficiency more affordable.
- **> Supports Environmental Justice**
  By addressing inequalities in housing thermal efficiency and energy security.

Introduction

Hurricane Katrina in 2005 set a deadly marker – an estimated 1,392 deaths – exceeded to date only by "2017's Hurricane Maria, which killed 2,981 in Puerto Rico and the U.S. Virgin Islands."[1]

Some areas of New Orleans lost power for weeks; some for more than a month. Long power outages have become a feature of extreme weather events, even as electricity has become more essential to sustaining life. Increased community resilience in the face of weather extremes and power outages has become a necessity for infrastructure design.

One hundred thousand families, mainly Black Americans, in New Orleans had no cars and could not flee Katrina's devastation; it was only one of the ways the community was disproportionately impacted, epitomizing the dreadful reality of pervasive inequalities.[2] Even some modern homes in New Orleans had to be temporarily abandoned because they became unlivable without air-conditioning; others of more traditional design, with wrap-around porches, cross-ventilation, and shading remained functional in the August heat.

Among the principles to emerge from an intensive review of the Katrina experience was that buildings should "Provide for passive survivability." Specifically, this means that:

> "Homes, schools, public buildings, and neighborhoods should be designed and built or rebuilt to serve as livable refuges in the event of crisis or breakdown of energy, water, and sewer systems."[3]

As climate extremes intensify, "passive survivability" during prolonged electricity outages has come to be seen as a necessary element of climate resilience. Building efficiency codes are essential to achieving it.[4]

Resilience in the face of climate extremes has many dimensions, including enabling communities to maintain essential services for health and safety. This includes maintaining uninterrupted electricity supply for critical services, like hospitals, gas stations, emergency response facilities, grocery stores, and emergency shelters during prolonged outages. This brief describes the role of building efficiency standards in increasing passive survivability. It also connects building efficiency-related resilience to other necessary elements of resilience, and points to the need for a holistic approach to resilience in the context of grid decarbonization.

Key Findings

1. **Strengthening building efficiency codes is an essential element of increasing resilience and improving health and safety.** Building efficiency standards allow homes to remain livable during long electricity outages resulting from extreme weather by slowing home heat gain in hot weather and heat loss during cold waves. Regularly updating building efficiency standards is essential as climate extremes worsen.
2. **Adoption of the IECC 2021 efficiency standards has benefit-cost ratios significantly greater than one for new residential construction.** Analysis by Department of Energy national laboratories shows that using IECC 2021 for new single family construction, and equivalents for new multi-family construction, would have large net resilience and climate benefits, including saving lives, across a range of climate regions.
3. **Benefit-cost analysis of investments in building efficiency retrofits must be more comprehensive.** Building efficiency retrofits are more expensive than achieving the same performance in new construction. Yet, they make utility bills more affordable and reduce severe financial stresses faced by low-income households, including rent/mortgage-utility bill payment conflicts that contribute to evictions and foreclosures. Mitigating these stresses provides large financial benefits for low-income households and also for non-low-income taxpayers, including tens of thousands of dollars of avoided health and housing costs for each prevented eviction or foreclosure. Comprehensive benefit assessment is not the norm today. It is needed to ensure that incomplete benefit-cost analysis does not lead to missed resilience and financial opportunities for all segments of society.
4. **Passive survivability during long outages provides a resilience floor that enhances the benefits of other necessary resilience investments.** Uninterrupted power for critical loads such as emergency shelters, emergency response facilities, hospitals, gas stations and grocery stores is an essential element of resilience as weather extremes worsen. Investments enabling low-income households keep on some lights and refrigerate food and medicine during outages would complement passive survivability increases and enable safer sheltering-in-place. Sound building efficiency standards complement other necessary resilience investments and increase their benefits.
5. **A holistic approach to resilience is necessary. Worsening climate extremes and long electricity grid outages have made a holistic approach to resilience necessary.** Efficient residential buildings that enable multi-day passive survivability, significant investments in distributed zero-emission resources that provide uninterrupted power to community-determined critical loads and vulnerable populations, community microgrids, and distribution system upgrades to accommodate various aspects of resilience are all part of holistic approach to resilience. While a detailed analysis is beyond the scope of this brief, the evidence shows that a failure to coordinate the various elements of resilience and grid decarbonization will mean increased costs and forgone opportunities, especially as transportation and heating are electrified. Yet the needed coordination is not in evidence today.

Passive Survivability and Building Efficiency Standards

Since 2020, the Department of Energy and some of its national laboratories have engaged in an intensive effort to examine the relation of building efficiency standards to resilience during periods of extreme heat or cold that are coincident with long electricity grid outages from the following points of view (Franconi et al. 2023, p. vi):

> Shelter-in-place capability

> Excess mortality

> Property damage

> Investment benefit–cost assessment

Metrics have been developed for each. The focus of this brief is "shelter-in-place" capability, which connects directly to building efficiency standards. A central technical feature of a structure that enables people to shelter in place is how well a building can retain a set temperature level in the absence of heating or air-conditioning when the outdoor temperature differs greatly from that setpoint. Building materials, wall, ceiling and floor insulation, and the quality and fit of windows and doors are all critical to the rate of a building's heat loss or gain. This thermal performance is the domain of building efficiency standards. These standards are periodically reviewed and updated by the International Code Council. Each review is issued as an "International Energy Conservation Code" (IECC) with the year of issue. The codes are geared to climate regions and are updated every three years. This brief discusses the standards in IECC 2021.

a. A Passive Survivability Metric

A metric is necessary to relate the concept of passive survivability to building efficiency standards. The first step is to define a range of livable temperatures – a minimum during cold spells and a maximum during hot spells. A very specific notion of temperature, called "the standard effective temperature (SET)," is used. It "is a comfort indicator that considers indoor dry-bulb temperature, relative humidity, mean surface radiant temperature, and air velocity, as well as the activity rate and clothing levels of occupants." (Franconi et al. 2023,p. vii). The minimum habitable temperature is set at 54°F for cold weather; the maximum is 86°F for hot weather. A time metric is also needed: how long will a home maintain the temperature in this habitable range?

The combined temperature-time unit is "degree-hours." For instance, if the home temperature during a cold spell is 1°F below 54°F for one hour, 3°F for another hour, and 4°F for a third hour, the cumulative degree-hours outside the habitable range for that period would be 8 SET degree-hours.[5]

The metric is standardized to a week-long period of extreme heat or cold that is coincident with an electricity outage. The U.S. Green Building Council gives a Leadership in Energy and Environmental Design (LEED) certificate to a building whose cumulative SET degree-hours do not exceed 216 over a week-long outage (Franconi et al. 2023, fn. 1, p. vii). That provides a specific metric against which to compare the standards to which buildings are built. The habitability of a residence during extreme heat or cold coincident with an outage is the number of days it takes for the cumulative indoor degree-hours beyond the SET limits to reach 216 degree-hours. The maximum is seven days, since that is the assumed length of the outage for the LEED certification.

Table 1 shows how the passive survivability approach with the specific LEED-designated SET-hour limit of 216 degree-hours can be used to evaluate the impact of building efficiency codes on resilience.

Table 1: Passive Survivability and Building Efficiency Standards – existing single-family homes compared to IECC 2021 compliant single-family structures

		EXISTING BUILDINGS	IECC 2021	EXISTING BUILDINGS	IECC 2021
Location and climate zone	**Extreme Weather Type**	**SET degree-hours** (7-day outage)		**# of habitable days** (maximum set at 7)	
Houston, TX (hot, humid, Zone 2A)	Cold	749	222	3.8	6.9
	Heat	600	141	4.0	7.0
Portland Oregon (mixed marine; Zone 4C)	Cold	2,963	1,849	1.1	2.4
	Heat	371	319	4.7	5.5
Detroit, MI (cool, humid; Zone 5A)	Cold	4,248	3,020	0.9	1.7
	Heat	223	53	6.8	7.0
Minneapolis, MN (cold, humid; Zone 6A)	Cold	5,397	3,699	0.6	1.2
	Heat	215	66	7.0	7.0

Source: Franconi et al. 2023,Table ES-1

During a cold spell with a long outage, typical existing single-family homes would be habitable for significantly more than one day in only one of the four cities shown – Houston. In one city, Portland, in a marine zone, a typical single-family home would be habitable for just over a day; in the other two, typical homes would not meet the habitability criterion for even one full day.

Adopting the IECC 2021 code would approximately double the habitability period in all four cities, allowing homes in Houston to be habitable for a full 7-day outage during a cold spell. During hot spells with a week-long outage, the IECC 2021 code would enable habitability for the full week-long outage in three of the four cities and not much short of that in the fourth.

The SET degree-hour metric clearly shows the efficacy of the IECC 2021 building efficiency code in increasing passive survivability. It also shows that in cold climates, the code would fall considerably short of seven-day habitability during a cold spell. More stringent "passive house" standards (not shown) would improve the picture but still fall short (Franconi et al. 2023, Table ES-1). These assessments show how the SET degree-hour approach provides a reliable metric for habitability. It is also a guide for situations where building standards may need to be supplemented by other measures to achieve desired resilience goals.

b. Strengths of the Passive Survivability Approach to Building Standards

Building efficiency standards have been a feature of the energy policy space since the 1970s. Initially, the main metrics related to the first cost of improved building efficiency and the lower energy use and cost achieved thereby. Climate change made building greenhouse gas emissions another essential consideration. With climate extremes and power outages, a safety metric for passive survivability has been added.

Increased passive survivability saves lives. Quantification of lives saved enables the use of insurance-type metrics to estimate corresponding dollar values that can be added to other dollar metrics, such as the value of avoided CO_2 emissions. This approach enables standard benefit-cost techniques to be applied as an aid to decision-making. As discussed below, an important caveat is that it is essential to include benefits outside the energy sector (called "non-energy benefits") to make sound policy and investment decisions, especially in regard to low- and moderate-income households.

Franconi et al. (2023) calculate that including the benefits of "energy cost savings, the societal value of reduced greenhouse gas emissions, and decreases in monetary losses associated with property damage and excess mortality" makes the benefit-cost ratio for detached single-family homes of adopting IECC 2021 significantly greater than 1.0 in all cases examined; the ratio ranges from 2.1 (Portland, Oregon) to 6.3 (Houston, Texas). Similar results were obtained for corresponding standards for multi-family structures.

c. Limitations of SET degree-hours

The results are less happy for benefit-cost ratios relating to retrofits. In almost all cases, the ratios are estimated as being less than 1.0 (Franconi et al.2023, Table ES-2), which would indicate that retrofits to the IECC 2021 level are not justified. One reason is that it is far more expensive to retrofit homes than build to specified standards in the first place. In the six cities considered in Franconi et al. (2023, Table 16), the annualized cost of building new single-family homes to IECC 2021 was estimated at between $0.03 and $0.07 a square foot. Retrofitting existing single-family homes to the same standard would cost between $0.63 and $0.70 a square foot.

However, the low benefit-cost ratios are also due to very partial benefit accounting, especially as it concerns low- and moderate-income households. For instance, health benefits other than reduced fatalities were not included (Franconi et al. 2023, pp. 52-53). Other major omitted benefits go under the rubric of "non-energy benefits," which are benefits that have substantial financial and/or societal value but are not included in traditional energy benefit-cost tests, such as the cost of utility rebates or customer retrofit investments compared to utility or customer cost savings. Specifically, lower utility bills made possible by efficiency investments alleviate severe financial stresses faced by low- and moderate-income households between paying rent or mortgage, buying food and medicine, and staying current on utility bills. A 2018 survey of households receiving energy bill assistance at least once in the prior five years found that[6]

- Over 30% of households used stoves or ovens for heating.
- About a third could not afford to fill their prescriptions completely.
- About a third went without food a day or more.
- On average, almost 5 percent became unhoused each year (23% over five years).

Every instance of preventing a family from becoming unhoused benefits the non-low-income public (taxpayers, health insurance companies, hospitals) to the tune of tens of thousands of dollars.[7] And that is just one avoided cost. Non-energy benefits, when comprehensively accounted for, may by themselves justify the public investments in stringent retrofits in low- and moderate-income homes. That would complement the substantial passive survivability and reduced CO_2 emission benefits they would provide.

Many people also need electricity for medical devices. For them, the loss of power even for a day or two may be intolerable, quite apart from indoor temperature. For low-income households with electric cooking ranges, the financial burden of eating out or buying prepared foods for all meals may quickly become unaffordable. As Franconi et al. (2023) note, back-up power may be a necessity in some circumstances.

Holistic consideration of resilience

Integrating passive survivability into building efficiency standards has become essential, but as the above discussion indicates, passive survivability improvement should be seen as a floor.

Moreover, in cold and very cold climates achieving multiple-day passive survivability to the metric of 216 SET degree-hours may be very expensive, requiring thermal performance well beyond passive house standards (see Table 1 above). In these cases (and possibly in others), highly efficient heating systems, such as geothermal networks or seasonal thermal storage that require minimal electricity to operate, may be required to complement building efficiency standards. An example of the latter is provided by Drake Landing Solar Community in Alberta, Canada, where a solar district heating system with seasonal thermal storage has reliably provided 90 to 100 percent of winter space heating requirements to 52 homes. Electricity is used to operate the system pumps.[8]

Passive survivability and related building efficiency standards, such as IECC 2021, are best seen as essential parts of a holistic approach to resilience. For one thing, outages can last much more than a week. There were areas of Puerto Rico that endured power outages of many months after Hurricane Maria in 2017. More recently, 14,000 customers were still without power in mid-October 2024, over two weeks after the devastating floods and winds of Hurricane Helene hit western North Carolina.[9] Rural areas are often disproportionately impacted, a characteristic shared with Black, Indigenous, and People of Color communities, whether urban or rural.

Meeting the needs of vulnerable populations, maintaining a minimum of viability of health, mobility, and communications during long outages requires elements of resilience that are well beyond the passive survivability floor. Specifically, they include ensuring uninterrupted electricity supply to critical loads in communities. A detailed consideration of these complementary resilience systems is beyond the scope of this brief. An example will suffice to show the need for a holistic approach to resilience, as well as the importance of building efficiency standards in that scheme.

Highland Park city is an enclave of Detroit, Michigan. Its population is nearly 86 percent Black; its median income is under 40 percent of the statewide level; the poverty rate is 41.2 percent (compared to 13.5 percent statewide). Over half the households are renters, compared to 27 percent statewide.[10] Renters have little or no control over improving passive survivability by investing in retrofits, even if they could afford them.

Long outages can be devastating, involving spoiled food and lack of livable shelter. Nationally, half the families with incomes below $25,000 per year would not be able to pay all their bills if they had an unexpected $400 expense.[11] In this context, long outages that cause the loss of food and medicines that families would not be able to replace and the necessity to buy more prepared foods can severely damage family finances and health.

To address a part of this problem in Highland Park, the National Renewable Energy Laboratory, in cooperation with the community, evaluated options for local power supply, including to the Ernest R.

Ford Recreation Center (hereafter "the Center") that could serve as a public shelter for a multi-day outage. Large refrigerators to enable sheltering families to store their food would be installed. Both diesel generators and solar-plus-battery-storage were considered. When the benefits of shelter, saved food, and avoided CO_2 emissions were included, a recent analysis for a rate case found that the solar-plus-storage project would be approximately cost-neutral. It would provide emergency shelter for about 200 people over a three-day outage.[12] But it should also be noted that the shelter would serve less than six percent of Highland Park households below the poverty level.

This example points up the necessity of retrofits of existing homes to high standards of passive survivability for existing homes, especially for low- and moderate-income households who have few options other than sheltering in place. Even in such cases, complementary investments are indicated. For instance, apartment buildings could be equipped with solar-plus-storage systems with appropriate inverters that could power critical loads (e.g., refrigerators, some lights, and medical devices) during outages.[13] Investments in the systematic use of vehicle-to-home (V2H) technology, which could allow public electric vehicles to supply power to homes with vulnerable populations, could also be explored. The usefulness of V2H technology has been illustrated recently in the aftermath of hurricanes, including Hurricane Helene.[14] Multi-day passive habitability would greatly enhance the value of such investments because it would ensure habitable indoor temperatures for longer periods if outages occurred during very hot or very cold weather.

Community microgrids that provide uninterrupted power to critical loads would complement passive survivability and small distributed solar energy sources with storage. For example, the Blue Lake Rancheria Tribal Nation microgrid in northern California served as an energy haven for its neighbors when Pacific Gas & Electric, the utility in the area, shut off electricity to millions of people in mid-October 2019 to reduce fire risk from its electrical system. People went to the Blue Lake Rancheria Tribal Nation to charge their phones; they filled up their cars at the functioning gas station, which also "provided diesel to United Indian Health Services to refrigerate their medications" as well as to a local fish hatchery. A local newspaper was able to go to print during the grid outage.[15]

The role of new renewable energy configurations, notably "plug-and-play" solar panels, in increasing resiliency during outages, especially for renters, should also be explored.[16]

Extreme heat and cold are just two types of climate extremes, which also include fires, floods, and more severe droughts that stress water supplies. Power failures may also be accompanied by failures of water treatment and sewer systems, as happened in the aftermath of Hurricane Helene. Even in such cases, building efficiency investments enable investments in uninterrupted power supply for emergency shelters, grocery stores, and similar facilities to endure for longer outages. In this context, regularly updating building efficiency standards is essential as climate extremes worsen.

In sum, building codes for passive survivability should be seen as a resilience floor, which would enable greater benefits from other necessary resilience investments, such as

- Maintaining uninterrupted power supply to community-defined critical loads, including hospitals, emergency response facilities, appropriately equipped public shelters, and strategically located gas stations and grocery stores.

- Installing sufficient solar-plus-storage in affordable housing to power critical loads, including refrigerators, some lights, and medical equipment.
- Installing geothermal heating networks or seasonal thermal storage heating in cold areas, especially those vulnerable to long outages.
- Promoting community microgrids that can, over time, be expanded to cover a larger fraction of loads as space heating and transportation are electrified.
- Integration of the various elements of energy system resilience, including building efficiency standards and uninterrupted power supply to critical loads during long outages, with decarbonization planning is essential for community health and safety. Unfortunately, the distributed zero-emission resources that are at the heart of holistic resilience design are not yet well-integrated into electric system decarbonization planning.

END NOTES

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[15] Erik Neumann, "California Reservation's Solar Microgrid Provides Power During Utility Shutoffs," Jefferson Public Radio, January 14, 2020.

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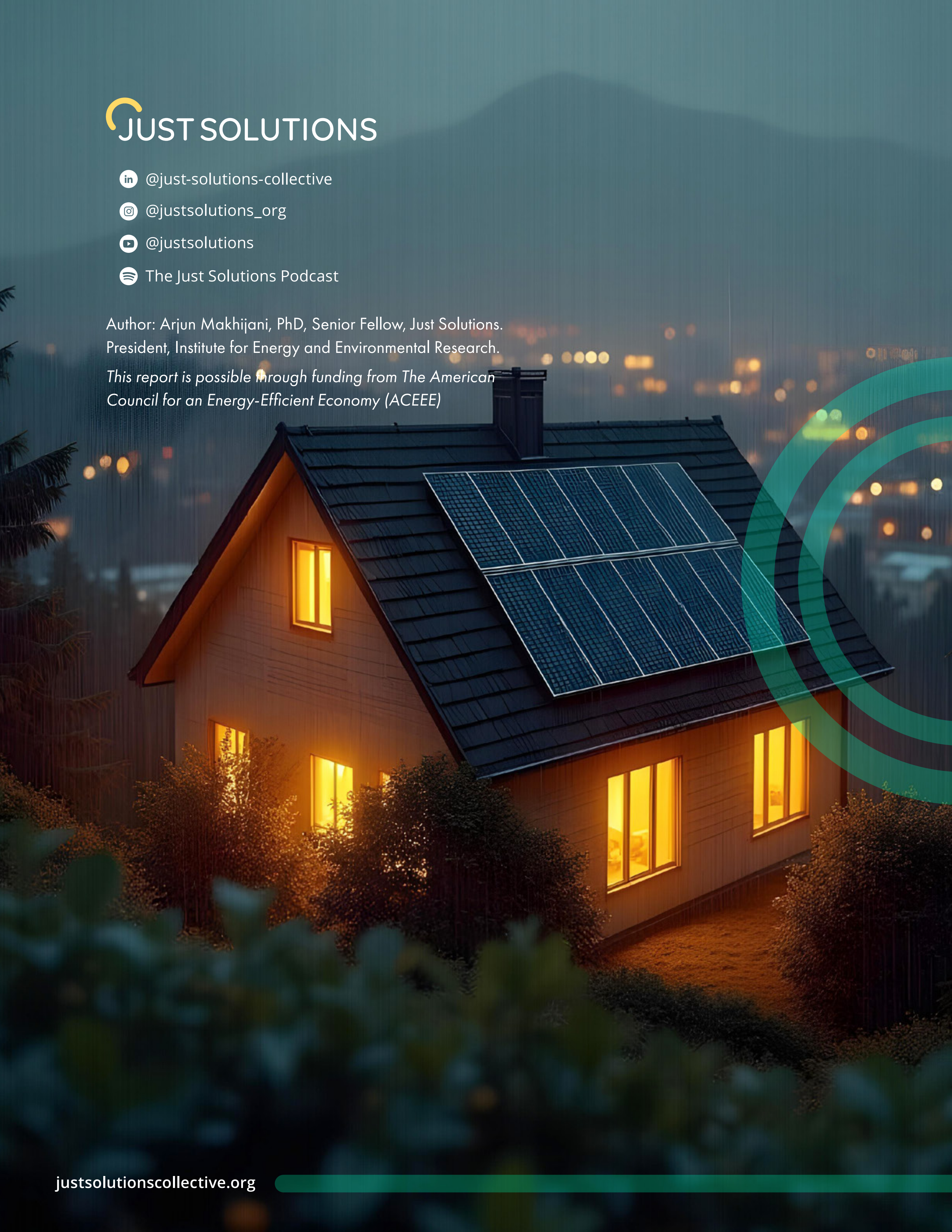

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This report is possible through funding from The American Council for an Energy-Efficient Economy (ACEEE)