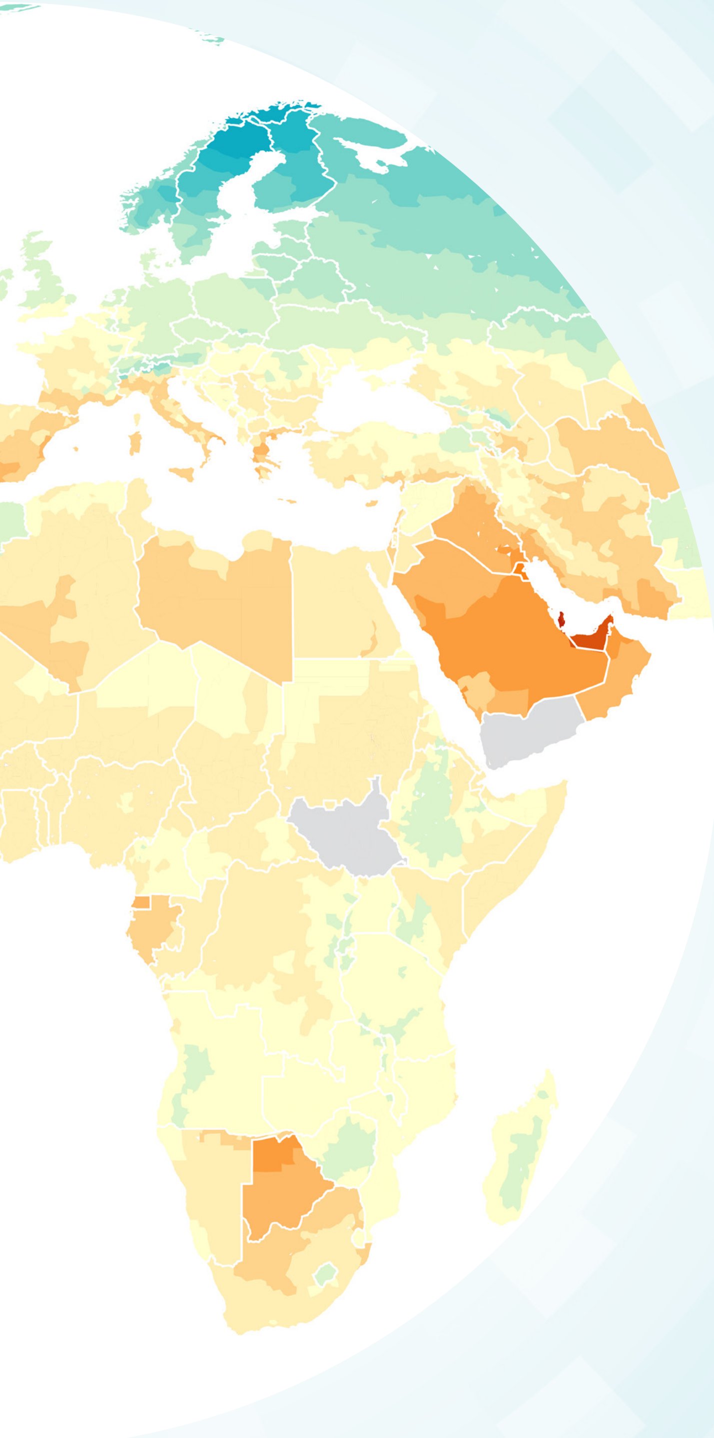

ADAPTATION ROADMAP

Energy

Measuring the impact of rising temperatures on energy consumption to target adaptation planning

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July 2026

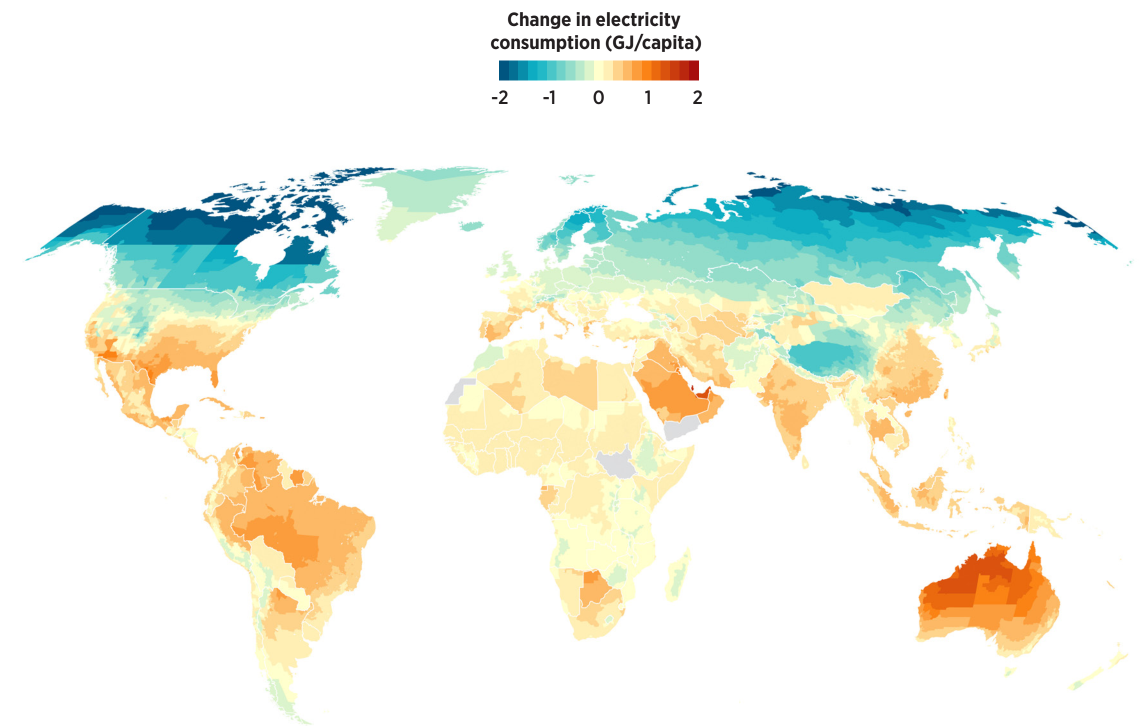
Climate Impact Lab

Executive Summary

Climate change will increase the importance of energy as a tool for adaptation. Climate Impact Lab (CIL) research indicates that climate-driven changes in temperature could contribute to approximately 430,000 additional deaths annually by 2050 compared to historical conditions. How many of those lives can be saved largely depends on access to energy, particularly the electricity needed for cooling. And yet, this report shows that many of the regions of the world most impacted also lack the energy needed to adapt—with 10 times more deaths occurring in poor countries by 2050 than in wealthier countries, according to Lab research.

Public health risks from climate change will be amplified by the unequal ability to use energy to adapt. This report identifies the regions around the world where energy consumption needed for climate adaptation will fall short, using CIL projections of climate-related changes in the consumption of electricity and heating fuels in 2050. Communities projected to lack sufficient growth in electricity consumption for cooling will be particularly vulnerable. Countries, communities, and funders who are focused on finding ways to save the greatest number of lives will increasingly need to consider reforms to electricity markets that allow more people to consume enough electricity to power cooling technologies, while also identifying adaptation measures that are less dependent on electricity-driven cooling.

Unequal Distribution of Changes in Energy Consumption



Note: Change in region-level electricity (GJ/capita) in 2050 compared to the 2001-2010 average due to climate change.

Adaptation Roadmap Series

This report is the second in a series that takes as its starting point the urgent need to embrace adaptation as a central part of the strategy to confront climate change, alongside greenhouse gas emissions mitigation. Just as one cannot get where they are going without a map, adaptation to climate change cannot succeed without knowing where it is needed most and what investments will deliver the greatest payoffs. This series provides that adaptation roadmap, identifying the impacts and locations where climate adaptation investments will be most beneficial. Each report in the series builds off landmark Climate Impact Lab research that leverages rich global data to uncover the relationship between increasing temperatures, adaptation, and human well-being, while accounting for the expected benefits of projected income growth over the coming decades.

Key Take Aways

Low-income countries will be the least able to increase electricity use to adapt to a warmer world.

Globally, annual electricity consumption is projected to increase by 0.17 GJ per capita (6%) on average by 2050, with some areas seeing an increase of as much as 3.3 GJ per capita. This increase is driven by both an increase in the need for cooling with climate change and an increase in the ability to pay for that increase due to rising incomes.

CIL research finds that only the world's richest populations currently have the resources and stable energy markets needed to power cooling. But as the climate warms, many middle-income countries will gain access to electricity. Today's middle-income countries are projected to increase consumption by 0.21 GJ per capita on average. That's seven times the increase low-income countries will experience—0.03 GJ per capita on average. The increase in electricity consumption in low-income countries is equivalent to the amount of electricity needed to power just a single LED bulb for four months. Critically, many of these low-income countries projected to see so little increase in electricity access are the same countries most exposed and vulnerable to extreme heat. This puts lives at risk and underscores the inequities of status quo adaptation capacity.

Further underscoring the inequality, wealthy countries like those in North America, Europe and parts of Asia will be the ones to benefit from less need for heating fuels as the world warms. Today's high-income countries are projected to see average declines in heating fuels consumption of 1.6 GJ per capita—eight times larger than the 0.2 GJ per capita decline projected for low-income countries. That amount of decreased energy use in wealthy countries would save a person in Europe €53 ($62) on their current natural gas bill and heat an average midwestern U.S. household for 3 days in the winter, demonstrating that even in these countries where climate change will have benefits, those benefits will be relatively modest.

Those living in regions with little increase in electricity consumption have the highest risk of dying from the heat.

Comparing projections of electricity consumption with projections of temperature-related mortality reveals a striking pattern. Wealthy communities will increase their use of electricity for cooling, while poor communities will not and will see significantly more heat-related deaths. We refer to this as the Mortality-Cooling Trap: countries experiencing the largest increases in heat-related mortality are often projected to see only very small increases in electricity consumption. As defined in the report, there are 18 countries caught in the heart of the Mortality-Cooling Trap. All of these are either low-income or lower middle-income today. Most are located in northern sub-Saharan Africa (e.g., Niger, Mali, Burkina Faso, Chad), while the remainder are concentrated in Southern Asia (Pakistan, Bangladesh, Nepal, Myanmar). More than 676 million people in these countries are projected to live in areas with significant increases in heat-related deaths and yet very low changes in electricity consumption (MCT Regions). As a result, approximately 377,000 lives are projected to be lost each year starting in 2050 due to warmer temperatures in Mortality-Cooling Trapped countries.

Adaptation measures beyond access to electricity will be critical to save lives.

These findings underscore a central challenge for adaptation planning: More electricity consumption is necessary to save lives, but this requires improvements in the functioning of electricity markets and higher incomes so people can afford electricity. Importantly, this means that electricity market reforms, which are not usually considered a form of climate adaptation, should become a key part of the adaptation toolbox. In some places, other adaptation measures will be needed. Policymakers and funders can look to measures such as heat early warning systems, heat action plans, urban greening, expanded healthcare access, and targeted social protection programs as options to improve the welfare of vulnerable communities but overall, these interventions still need more rigorous testing to establish their efficacy. More information about approaches that have been proven to be effective is available in the CIL Adaptation Inventory.

Countries in the Mortality-Cooling Trap

Country	Change in mortality in MCT Regions (Deaths/100k)	Change in electricity consumption in MCT Regions (GJ/capita)	Portion of population living in MCT Regions
Niger	67	0.07	100%
Mali	36	0.07	99%
Burkina Faso	59	0.06	99%
Chad	46	0.07	97%
Pakistan	57	-0.03	89%
Bangladesh	27	0.02	81%
Somalia	33	0.06	77%
Guinea-Bissau	20	0.06	76%
Togo	36	0.07	75%
Mauritania	54	0.07	53%
Syria	31	-0.01	50%
Gambia	20	0.07	45%
Senegal	28	0.06	43%
Benin	32	0.07	42%
Nepal	24	-0.01	32%
Ghana	30	0.07	31%
Central African Republic	24	0.05	30%
Myanmar	18	0.05	26%

Note: Listed in decreasing order of the percent of their population that live in MCT Regions. Their population-weighted average change in mortality (deaths/100k) and electricity consumption (GJ/capita) in 2050 compared to the 2001-2010 average due to climate change in MCT regions, and the portion of total population (%) living in MCT Regions are shown

PREFACE

Climate change is already reshaping lives, communities, and economies around the world - and decision makers at every level need to know how and where to respond. The mission of the Climate Impact Lab (CIL) is to provide those answers via decision-relevant tools for governments, funders, multilateral institutions, and communities. Its global network of economists, climate scientists, and data engineers identifies where climate adaptation and resilience are most urgent and what investments will deliver the greatest benefits to communities. These insights are rooted in a decade of research yielding empirical, data-driven, hyper-local projections of how climate change will reshape human welfare across mortality, energy demand, agriculture, coastal flooding, and labor supply—quantifying not only what climate change will cost, but where intervention can reduce that cost, for whom, and at what scale.

CIL's Adaptation Roadmap Report Series distills this research sector by sector into clear guidance for policymakers, practitioners, and funders. The first report, focused on human health, found that climate change dramatically elevates mortality risk in the world's poorest regions. This second report in the series takes that finding a step further. The uneven distribution of temperature-related mortality aligns with a similarly uneven capacity to respond: the people most at risk of dying from extreme heat are also the least able to access the electricity-driven cooling that could protect them. We call this the Mortality-Cooling Trap, and this report maps where it is most severe, who bears its burden, and what it will take to close the gap.

Introduction

Climate Impact Lab (CIL) research indicates that climate-driven changes in temperature will cause approximately 430,000 more lives to be lost annually in 2050 compared to historical levels. This mortality burden is not evenly distributed: heat-related deaths are projected to be 10 times larger in poor countries than in wealthy ones by 2050. The findings contained in this report further accentuate this inequality, by highlighting that the tools needed to address these threats—access to cooling in particular—will be least accessible to those who need them most. The relationship between income, energy consumption, and adaptive capacity to heat is critical for the adaptation funding decisions made by communities, countries, and philanthropies around the world.

CIL research provides further insight into that relationship, having quantified the effect of temperature on electricity and heating fuels (e.g., natural gas, coal)[1] consumption across use in the residential, commercial, and industrial sectors (Rode et al., 2021). Using data from 146 countries over 40 years, the study also measures how this effect differs across income levels and climate conditions. It demonstrates that only the world's richest populations show evidence of using electricity to protect themselves via cooling during extreme heat or heating during extreme cold, while all but the poorest 20% of the world's population show evidence of consuming non-electricity fuels for heating on extremely cold days (e.g., through the burning of biomass). These different energy use patterns by fuel and by income play an important role in the projected changes in energy consumption due to climate change and implications for adaptation priorities as laid out in the analysis to follow.

1 The "heating fuels" category of energy sources, referred to as "other fuels" in Rode et al. (2021), is used throughout the report and includes coal, peat, oil shale and oil sands, oil products, natural gas, solar, wind, geothermal, biofuels and waste, heat, and heat production from non-specified combustible fuels.

In the future, a warmer climate will increase demand for cooling. At the same time, there will be less demand for heating fuels, such as natural gas. In the background, poorly functioning energy markets are a key factor in hindering reliable (or any) electricity service in many lower income countries (Burgess et al., 2020), and energy infrastructure in many locations are not prepared for additional demand expected with higher temperatures.

This generates a rich and complex role for energy in climate adaptation. On the one hand, a projected increase in energy consumption under climate change, particularly electricity consumption, can be viewed as a signal of a community's ability to adapt to increasing temperatures through the use of air conditioning that has been shown to save lives (Barreca et al., 2016). On the other hand, increased consumption can put stress on underlying infrastructure that then requires its own set of adaptation and development priorities to support increased demand. These tensions—and their implications for adaptation decisions—are summarized further below as we lay out the projected changes in energy consumption and their implications for adapting to a warmer world.

In this report, the second in the Adaptation Roadmap series, we seek to inform public and philanthropic adaptation funding strategies and provide insights to decision-makers on the relative priorities for climate adaptation related to energy consumption. We do so by assessing the geographic disparities in changes in consumption of electricity and heating fuel, highlighting the role that income plays in those disparities. We then show how energy-based adaptation constraints can be harmful, including their impact on temperature-related mortality. Throughout the discussion, we draw on the CIL Adaptation Inventory to connect projected energy consumption outcomes to relevant, proven-effective adaptation solutions that could be leveraged to improve human welfare.

Analysis background

In order to understand the critical relationship between temperature, income, and energy consumption, we leverage the temperature-energy consumption models developed in Rode et al. (2021) and follow an analysis specification consistent with that used in the first report in the series, Adaptation Roadmap: Human Health. This includes focusing on impacts of climate change in 2050[2] assuming the world is on track for roughly 3°C[3] of warming by the end of the century. For population and economic growth, we use the central "Middle of the Road" SSP2 scenario used by the Intergovernmental Panel on Climate Change (Fricko et al., 2017), as modeled by IIASA[4] (Riahi et al., 2017).

2 Results represent a 20-year average centered on 2050 (i.e., 2040-2059).

3 3°C warming level represents an increase in Global Mean Surface Temperature (GMST) at 2100 compared to that during pre-industrial time period (1850-1900). On that trajectory, the GMST in 2050 will be approximately 2.1°C warmer than the pre-industrial period.

4 This analysis is based on the SSP database hosted by the IIASA Energy Program at https://tntcat.iiasa.ac.at/SspDb.

CIL research helps to identify the places where further adaptation investments by people, governments, and funders can save lives.

Like other research from CIL, this analysis reflects the effects of "status quo" behavioral adaptations: the actions that communities will take as their incomes increase and as they are gradually exposed to warmer climates. Many of those self-directed adaptations (often referred to as autonomous adaptation in economics research) are income driven, such as managing exposure to extreme heat by increasing access to air conditioning, while others are climate driven, such as decreasing expenditure of heating fuels to heat homes when experiencing cold temperatures. By accounting for these autonomous interventions, the CIL work helps to identify the places where *further* adaptation investments by people, governments, and funders can be additive and support human welfare.

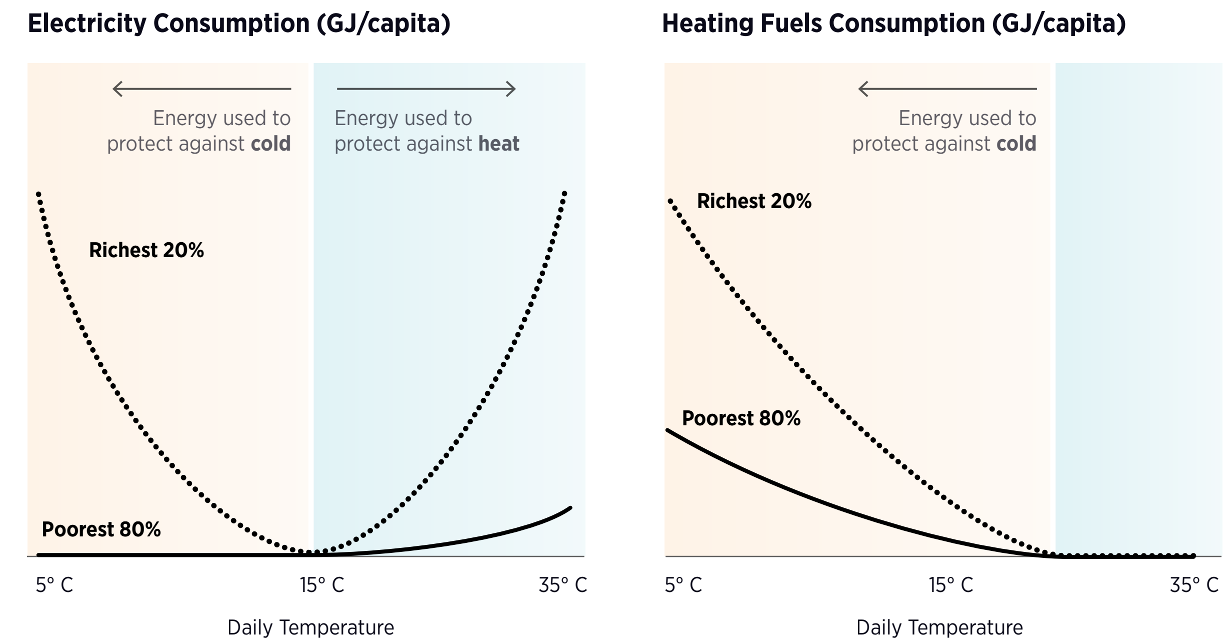
As the climate warms, there is a general expectation for an increase in the demand for cooling and a decrease in the demand for heating. The tendency to use electricity for both cooling and heating, and heating fuels primarily for just heating (Rode et al., 2021), influences the geospatial patterns of projected changes in consumption of both energy sources. We therefore look at that projected behavior for those sources separately.

Whether households and businesses can effectively use energy to respond to extreme temperatures depends critically on available financial resources and the stability of the energy market and infrastructure. Thus, local income emerges as a key driver of the degree to which energy responds to temperature fluctuations (Rode et al., 2021). Figure 1 provides an illustration of this relationship for electricity and heating fuels, differentiating the response for the richest 20% of the world's population from that of the remaining 80%.[5]

The role of income is especially stark when considering consumption of electricity. Only the richest communities across the globe use electricity to cool their buildings when exposed to high temperatures and heat their buildings in cold temperatures. That distinct U-shaped relationship between electricity consumption and temperature—where the consumption of electricity

5 Note that while Figure 1 leverages the same income split (80%/20%) for the response of electricity and heating fuels consumption for visual consistency, data from Rode et. al (2021) clearly shows that the income threshold for using electricity to cool on hot days is much higher than that for heating fuels on cold days such that the richest 40% of the population uses heating fuels to protect against the cold.

Figure 1. Stylized relationship between energy consumption and temperature for the richest 20% and poorest 80% of the world's population for electricity and heating fuels



Note: Adapted from Figure 1a in Rode et al. (2021).

to protect against cold decreases as temperatures rise until approximately 15°C/59°F and then increases to protect against heat—is virtually absent for the remaining 80% of the global population, as seen in the relatively flat relationship in Figure 1.

Meanwhile, the consumption of heating fuels declines with rising temperatures until approximately 20°C/68°F, where consumption is near zero. That L-shaped relationship is not present for most of the relatively poor, reflecting a low level of consumption for heating regardless of temperature.

Figure 1 makes clear that income will play a critical role in determining how energy consumption will change under a warming climate. In particular, energy-intensive cooling technologies such as air conditioning remain out of reach for all but the highest present-day global income levels. As incomes grow in future decades, energy consumption responses will evolve, reshaping the effects of future climate change on energy demand. Prior modeling efforts have generally omitted the role of income when estimating shifting energy consumption under climate change. Instead, our analysis and CIL's projections account for this force, allowing us to identify those areas of the world that—even with projected income growth—will likely lack the ability to adapt to higher temperature through cooling technologies without external support.

This information reveals where status quo adaptation is insufficient. International aid agencies, private philanthropies, and national, state, and city governments can use this analysis to prioritize actions in exactly the localities where energy-based adaptation to heat will be lacking, including market-, infrastructure-, policy- and income support-based approaches. They can also leverage it to inform where investment in adaptation strategies enhancing access to electricity, and/or interventions less dependent on electricity, will have the most impact.

Understanding the Disparity of Temperature-Related Energy Consumption: Geographic Priorities for Adaptation

The impact of rising global temperatures on energy consumption will differ dramatically around the globe. Figures 2 and 5 show the change in consumption of electricity and heating fuels for the 24,378 Impact Regions[6] that together comprise the world in CIL research[7].

6 The 24,378 Impact Regions (hereafter "regions") in the CIL's models provide a consistent, granular underlying spatial reference for all its research. They are agglomerated from second administrative units across the globe based on maintaining approximately similar population and average climate within each region (Rode et al., 2021; Carleton et al., 2022). For reference, their size is similar to that of counties in the United States and China.

7 Note that projections were not made for South Sudan, Western Sahara, and Yemen due to lack of information in IIASA SSP model.

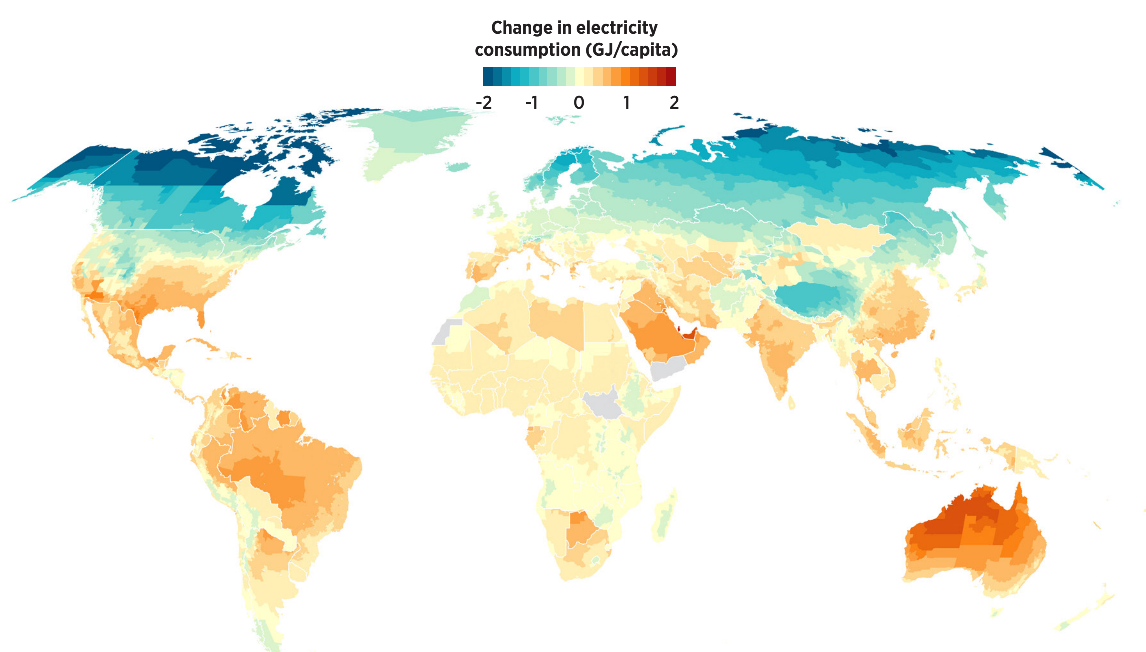
Changes in electricity consumption

Globally, electricity consumption is expected to increase 0.17 GJ/capita on average (6% increase from current consumption), which is similar to the amount of electricity required to power a household for essential use for approximately one month[8]. This relatively modest average reflects outcomes around the globe ranging from a decrease of 1.6 GJ/capita to an increase of 3.3 GJ/capita, with higher consumption being driven by both an increase in the need for cooling due to climate change and an increase in the ability to pay for that increase due to rising incomes.

Overall, we project that relatively warm areas, such as parts of the tropics and mid-latitudes, will use more electricity as they adapt to the heat through cooling technologies. But importantly, this is the case only for areas that are wealthy enough to afford those technologies, effectively leaving out most of the low-income countries from being able to leverage

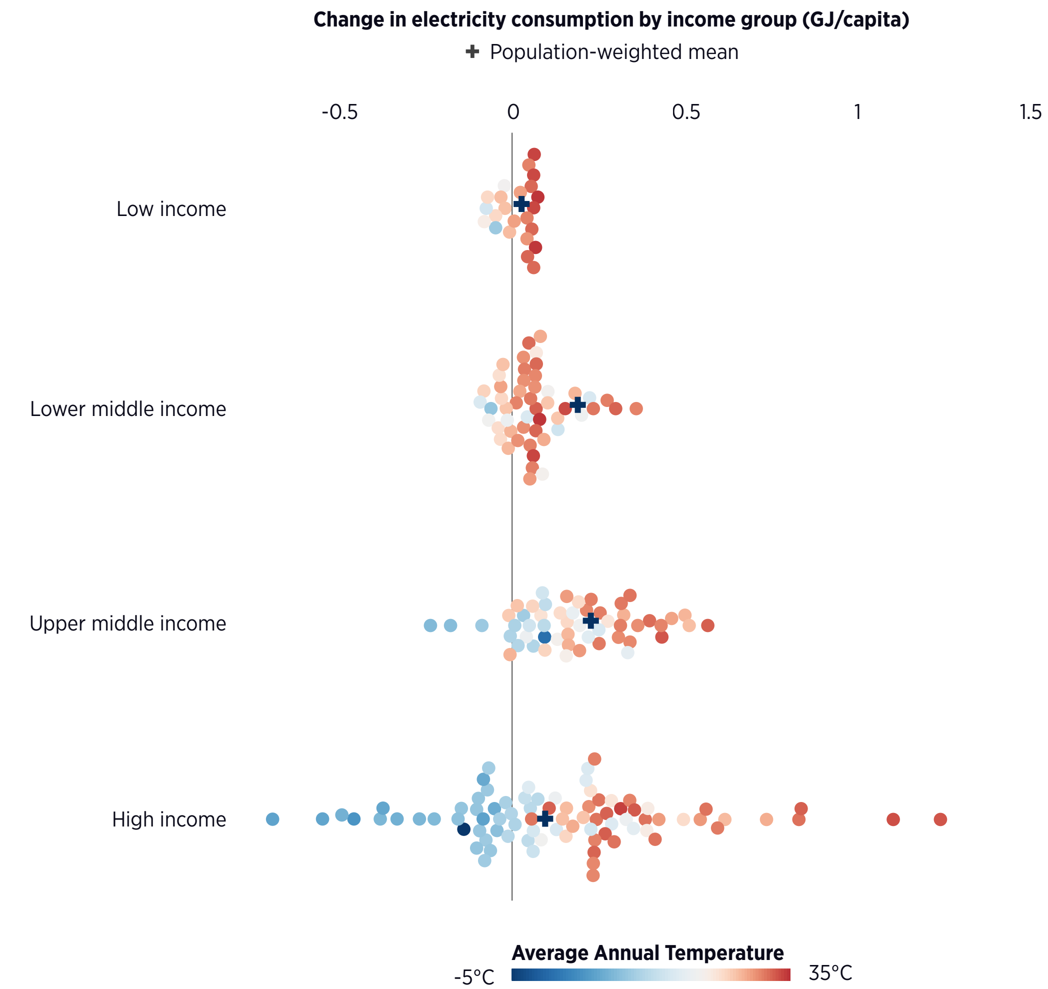
8 Based on the IEA (2024) methodology, essential use aligns to four lightbulbs operating four hours per day, a fan three hours per day, and a television two hours per day.

Figure 2. Change in annual region-level consumption of electricity (GJ/capita) in 2050 compared to the 2001-2010 average due to climate change



Note: Positive values indicate an increase in consumption. Negative values indicate a decrease in consumption.

Figure 3. Country-level average annual temperature in 2050 (°C) and change in annual region-level consumption of electricity (GJ/capita) in 2050, compared to the 2001-2010 average due to climate change

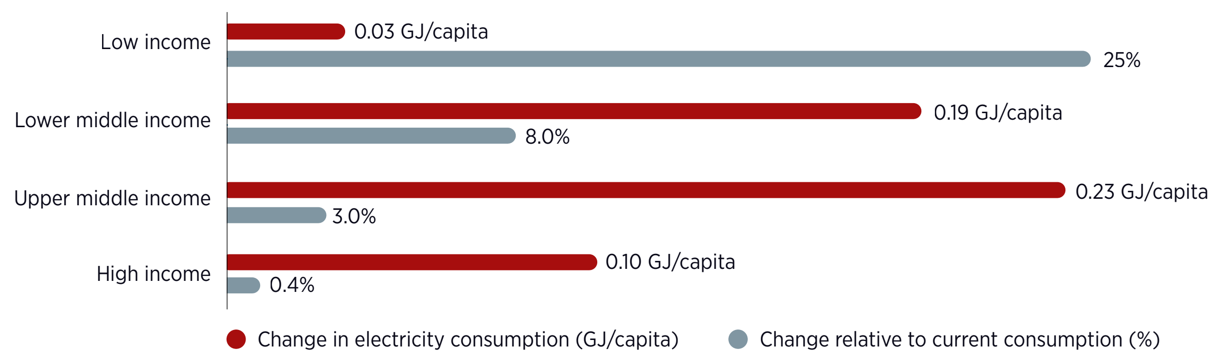


Note: Grouped by World Bank income categories (World Bank, 2025).

electricity as a primary means to adapt to heat (Figure 3). In fact, the increase in electricity consumption projected for the upper and lower middle-income countries (0.21 GJ/capita)—where income growth will support their ability to increase consumption as a means for adaptation—is approximately seven times that of low-income countries (0.03 GJ/capita).

We find that the lack of economic growth in today's low-income countries—including much of Africa—will continue to leave cooling technologies financially out of reach for many. These poor countries, which tend to be warmer than other income groups (Figure 3), will miss out on the opportunity to leverage that most well-proven heat adaptation strategy. Instead, the policymakers and funders that support them may look to adaptations that are less dependent on electricity to manage impacts to human welfare. While the adaptation community needs much more evaluation of interventions to understand and establish their efficacy, the CIL Adaptation Inventory identifies those interventions that do have rigorous studies demonstrating their effectiveness. Examples from the Inventory of policy-driven strategies to reduce the welfare impacts of heat include a range of options focused on income creation that support household-level access to electricity (e.g., Sarmiento, et al., 2024) as well as heat early warning systems and healthcare expansion programs, both of which are discussed more below.

Figure 4. Change in annual electricity consumption in 2050 compared to the 2001-2010 average due to climate change in absolute terms (GJ/capita) and relative to current consumption (%)



Note: Grouped by World Bank income categories (World Bank, 2025).

Further underscoring the inequality related to climate change's impact on energy consumption, the high latitudes of North America, Europe, and Asia—which includes many high-income countries—are projected to see a decrease in electricity consumption (Figure 2). This is because any increase in electricity demand for cooling (relatively less than in hotter climates) is balanced out by a greater decline in electricity demand for heating.

Although projected increases in electricity use can suggest progress for human welfare as a signal of communities adapting to heat via additional access to cooling, those increases will also impose new costs on the same communities as they seek to advance their physical infrastructure to keep pace with rising electricity demand. While the magnitude of projected change in use of electricity in low-income countries is quite small (0.03 GJ/capita), it reflects a significant rise in consumption compared to current levels (25%; Figure 4). Similarly, lower-middle income countries are projected to see an increase of more than 8% compared to current levels. In many of these low- and lower-middle income countries, current energy markets do not function effectively (Burgess et al., 2020), and current infrastructure is already stressed or does not provide reliable access to its full population. For example, over half of rural households in India experience electricity outages multiple times per day (IRES, 2020). Projected increases in demand, even modest ones, highlight the potential to further stress the existing grid, suggesting energy market reform and infrastructure development and resiliency could play an important role in adaptation planning focused on managing extreme heat, particularly in low- and lower-middle income countries.

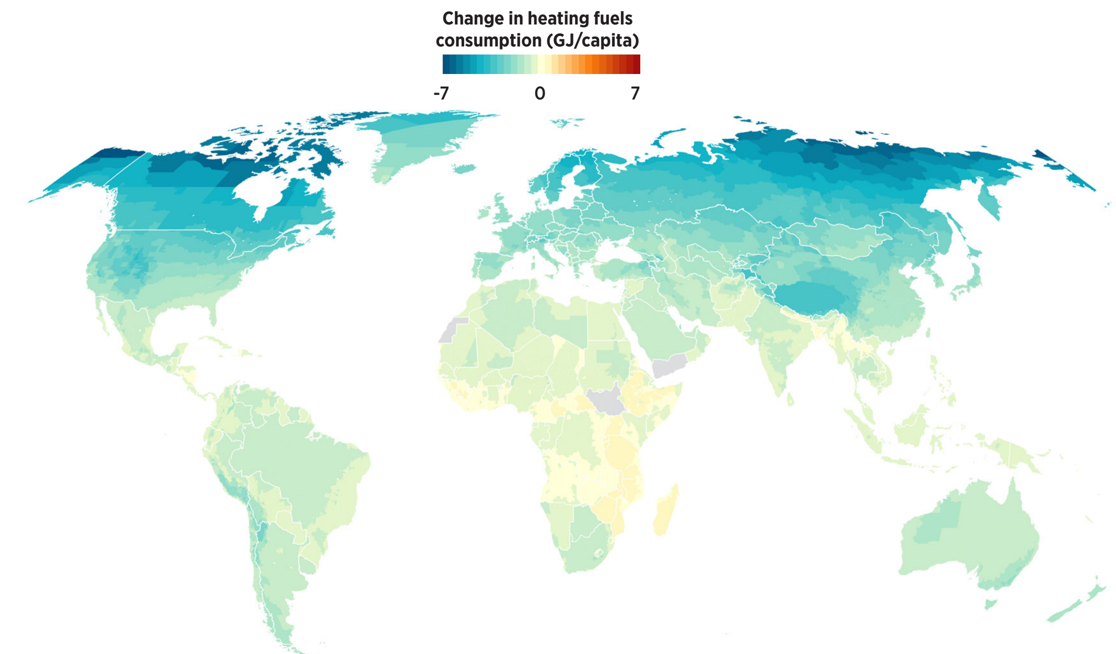
Changes in heating fuels consumption

Globally, the annual use of heating fuel decreases by 0.74 GJ/capita[9] (3% decrease compared to current consumption), similar to the amount of natural gas used to heat an average U.S. household for 1.5 days in the winter. This decrease in consumption is largest in the mid- and high latitudes (Figure 5), which is consistent with the overall decline in heating demand. In many of these richer and relatively colder areas in the northern hemisphere—including the northern tier of the United States, Canada, and northern Europe—the annual use of heating fuels declines by more than 2 GJ/capita, roughly equivalent to a savings of €67 ($78) per person on a current natural gas bill in the European Union.

On average, heating fuels decline by 1.6 GJ/capita in high-income countries—a decline that's eight times larger than that projected in the relatively warmer low-income countries (0.2 GJ/capita; Figure 6). This disparity in the projected changes in heating fuel consumption signifies the inequity in how climate change will affect different economic groups, as savings associated with lower demand for heating will fall primarily on the world's wealthy.

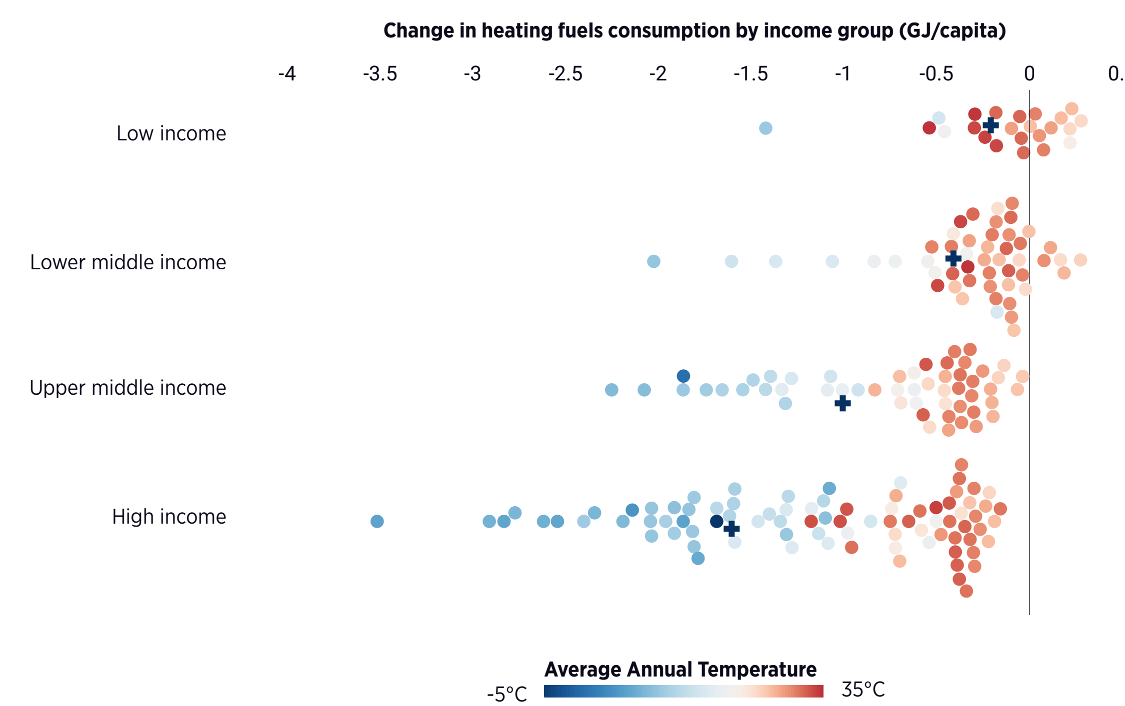
9 Note that while 1 GJ of electricity and 1 GJ of heating fuels contain the same amount of energy, they differ in several ways, including generation efficiency and utility. We therefore advise that the magnitudes of changes in electricity and heating fuels should not be considered an apples-to-apples comparison.

Figure 5. Change in annual region-level consumption (GJ/capita) of heating fuels in 2050 compared to the 2001-2010 average due to climate change



Note: Positive values indicate an increase in consumption. Negative values indicate a decrease in consumption.

Figure 6. Country-level average annual temperature in 2050 (°C) and change in annual consumption of heating fuels (GJ/capita) in 2050, compared to the 2001-2010 average due to climate change



Note: Grouped by World Bank income categories (World Bank, 2025)

Identifying the Mortality-Cooling Trap

The role income and future economic growth play in our ability to adapt to higher temperatures is common across many areas of climate change impacts. As noted in CIL's Adaptation Roadmap: Human Health report, climate change is projected to cause ten times more people to die in poor countries than wealthier countries, a disparity similar to that discussed above for climate change-driven changes in electricity consumption. Understanding the connection between these projections—mortality due to heat and electricity consumption to adapt to that heat—can help inform adaptation priorities and potential impacts of non-action.

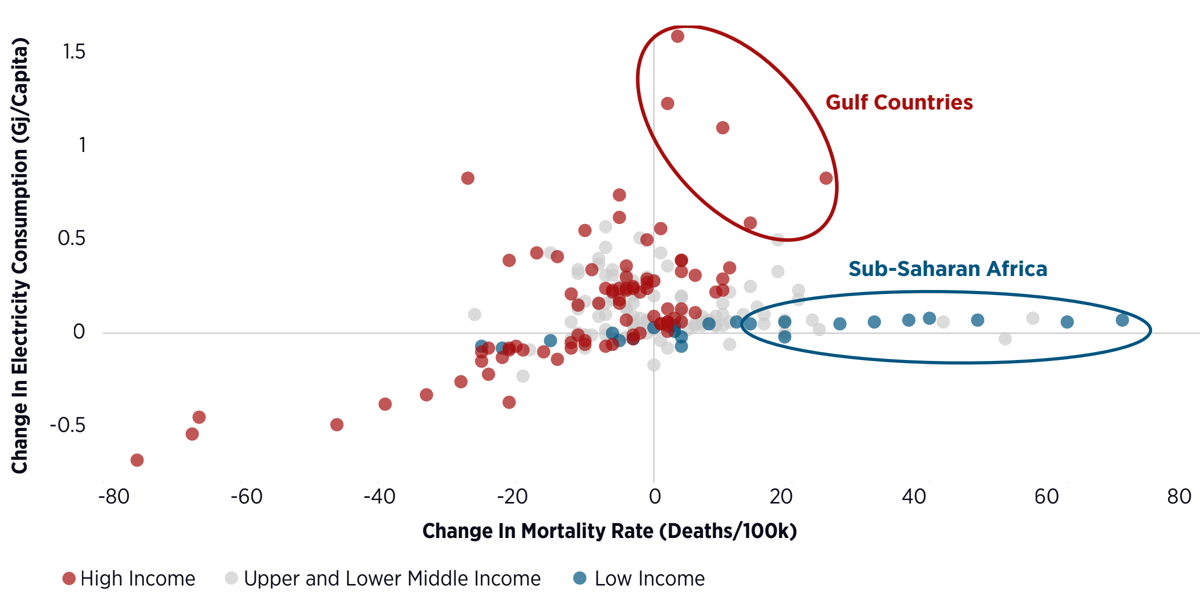
Countries projected to see large increases in temperature-related mortality (i.e., exceeding ~15 additional deaths/100,000) tend to also be projected to see relatively small changes in electricity consumption (Figure 7). This alignment is particularly present in today's low-income countries, including those across the northern portion of Sub-Saharan Africa, such as Niger, Burkina Faso, and Chad, and sits in stark contrast to wealthy countries, including those across the Gulf, such as Bahrain, Kuwait, and Saudia Arabia. These are two regions with similar hot climates, but one will see modest mortality effects and large increases in electricity consumption, while the other will suffer large losses of life and almost no increase in electricity consumption to help protect itself.

Narrowing our focus to where relatively small changes of electricity consumption align with significant increases in temperature-related mortality reveals a pattern we refer to as the **Mortality-Cooling Trap (MCT)**. *These "trapped" areas are the ones that would most benefit from increasing consumption of electricity to improve human welfare, particularly by saving lives, but are not projected to do so.*

Figure 8 lists the countries that are in the heart of this MCT. At least 25% of the population in each of these countries live in regions with both relatively large projected changes in temperature-related mortality (i.e., exceeding 15 deaths/100,000) and relatively small changes in electricity consumption (i.e., below 0.07 GJ/capita) (referred to as MCT Regions in Figure 8).[10]

10 These thresholds align to the 90th percentile of net changes in temperature-related mortality and the 25th percentile of the absolute value of electricity consumption for all 24,378 regions across the globe.

Figure 7. Change in country-level annual electricity consumption (vertical axis; GJ/capita) and temperature-related mortality (horizontal axis; deaths/100,000 people) in 2050 compared to the 2001-2010 average due to climate change



Note: Grouped by World Bank income categories (World Bank, 2025).

Figure 8. Countries in the Mortality-Cooling Trap

Country	**Change in mortality in MCT Regions** (Deaths/100k)	**Change in electricity consumption in MCT Regions** (GJ/capita)	**Portion of population living in MCT Regions**
Niger	67	0.07	100%
Mali	36	0.07	99%
Burkina Faso	59	0.06	99%
Chad	46	0.07	97%
Pakistan	57	-0.03	89%
Bangladesh	27	0.02	81%
Somalia	33	0.06	77%
Guinea-Bissau	20	0.06	76%
Togo	36	0.07	75%
Mauritania	54	0.07	53%
Syria	31	-0.01	50%
Gambia	20	0.07	45%
Senegal	28	0.06	43%
Benin	32	0.07	42%
Nepal	24	-0.01	32%
Ghana	30	0.07	31%
Central African Republic	24	0.05	30%
Myanmar	18	0.05	26%

Note: Listed in decreasing order of the percent of their population that live in MCT Regions. Their population-weighted average change in mortality (deaths/100k) and electricity consumption (GJ/capita) in 2050 compared to the 2001-2010 average due to climate change in MCT regions, and the portion of total population (%) living in MCT Regions are shown.

Staying true to the climate and income-driven trends discussed above, the 18 countries caught in the MCT are geographically concentrated and economically similar. All of them are currently either low (10) or lower-middle (8) income. Thirteen of them are situated in northern Sub-Saharan Africa, with Niger, Mali, Burkina Faso and Chad projected to experience high mortality and low electricity changes across most, if not all, of their population. The remainder are primarily located across southern Asia, including Pakistan, Bangladesh, Nepal, and Myanmar. More than 676 million people in these countries will live in areas with both significant increases in temperature-related mortality and very low changes in electricity consumption and approximately 377,000 lives are projected to be lost due to climate-driven changes in temperature in MCT countries.

Adaptation to heat is often a particular point of discussion in urban areas as infrastructure and lower vegetation exacerbate extreme heat. Many cities in MCT countries are projected to experience only small increases in electricity consumption, bringing challenges for electricity-dependent adaptation measures. When considering the largest city in each MCT country by population, together accounting for more than 80 million people in their metro areas, all 18 of them are projected to see increases in electricity consumption that are below the global median, and 10 of them are also projected to experience significant net increases in temperature-related mortality. Across the globe, more than 20 large cities[11] exceed those same thresholds, with Pakistan (9 cities), Bangladesh (2 cities), and Sudan (2 cities) having the most, highlighting areas that will be hindered from adapting to heat via electricity-dependent interventions.

There are adaptation measures that are less dependent on electricity and, according to the CIL Adaptation Inventory, have been proven to be effective in supporting positive health outcomes, particularly in urban areas, including heat early warning systems, heat action plans, and improving the temperature forecasts that inform them. Improving the accuracy of temperature forecasts in the United States by 50% was shown to save more than 2000 lives each year (Shrader, Bakkensen and Lemoine, 2023). Targeting the temperature threshold that triggers heat advisories and then implementing heat action plans that raise public awareness about the importance of reducing exposure and prompts actions in the health care network (e.g., increased visits of home care patients, water availability, and monitoring of heat-related symptoms) have been shown to decrease hospitalizations of older adults and cut mortality overall by more than half on hot days (Benmarhnia et al., 2016; Benmarhnia et al., 2019; Pavanello, and Valenti, 2025).

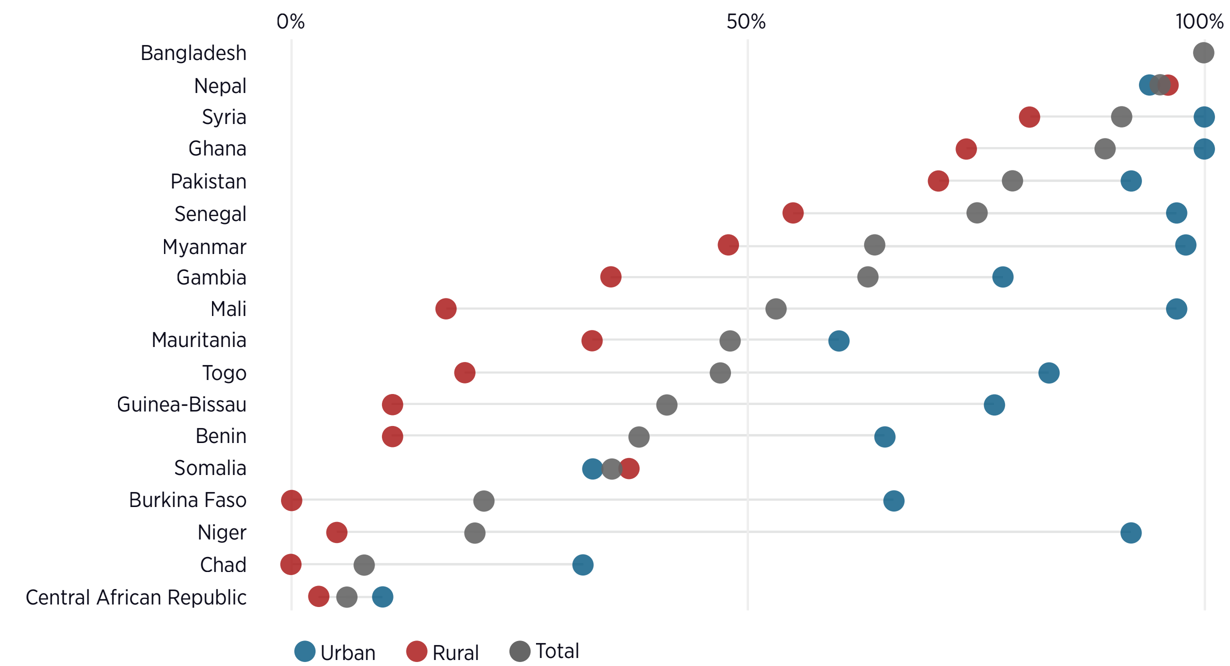
Compared to urban areas, rural areas in many of the MCT countries face an even more fundamental climate adaptation challenge than lack of growth in their consumption of electricity. Many of the rural populations in these regions currently lack consistent access to electricity at all (Figure 9). Bangladesh is the only country in the group that has near complete access to electricity for essential household use, according to the IEA (2024)[12]. At least 70% of the urban populations in 12 of the 18 MCT countries have access to electricity, but only five of them have essential electricity access for at least 70% of their rural populations. Furthermore, in eight countries, less than 20% of the population in rural communities have electricity access, including Chad, Burkina Faso, Central African Republic, Niger, Guinea-Bissau, Benin, Mali, and Togo.

These same rural areas also often have challenges with access to healthcare, which adds to their challenge of supporting heat-related adaptation measures as expanding healthcare access is a common focus of adaptation measures for managing the health impacts of heat. Examples of relevant effective interventions include demonstrated improvement in temperature-related mortality rates with increase access to community health centers (Mullins and White, 2020) —a benefit of investments in strengthening health systems—and declines in temperature-related infant mortality associated with in-home pre-natal visits in rural areas in India (Banerjee and Maharaj, 2020).

11 Cities must have a current population of at least 500,000 people to be included.

12 Note that these estimates for access to electricity for essential household use are extremely helpful benchmarks for adaptation planning and priorities, but are likely overestimating the level of access to electricity that is sufficient to support regular cooling as a means of adaptation.

Figure 9. Percent of the total, urban, and rural population with access to electricity for each of the 18 countries identified above in the Mortality-Cooling Trap



Note: Adapted from IEA (2024). Countries are listed in decreasing order of the portion of the total population with electricity access.

Implications for adaptation priorities

The inequity that often characterizes climate change impacts rings true to climate-related changes in energy consumption. While the globe will see an overall decline in the use of heating fuels as the climate warms, the benefits of those decreases will largely be seen for the wealthy. And the heterogeneity seen in projected changes in electricity consumption are strongly related to relative wealth as well, with high income countries expected to increase consumption as a means to adapt to heat and low-income countries often lacking the financial means and infrastructure to do so. Those areas projected to see relatively stagnant levels of electricity use strongly overlap those that are projected to see the largest increases in temperature-related mortality, revealing a clear Mortality-Cooling Trap.

While there is significant need to broaden the rigorous study of adaptation interventions, we have noted a diverse set of effective adaptation measures that can be implemented to meet the needs of communities as they seek to adapt to higher exposure to heat. The projected changes in climate-related energy consumption discussed here can inform decisions around the type and prioritization of adaptation interventions that can be implemented to save lives.

For those areas projected to see increases in electricity consumption as a means to adapt to heat, there may need to be a focus on the continued development and hardening of the electricity infrastructure that will be required to support the higher demand. For those areas that are not expected to see material changes in their electricity use, either through a lack of financial means or sufficient infrastructure, adaptation options include reforms to electricity markets that allow more people to consume enough electricity to power cooling technologies as well as more localized interventions that have been shown to be effective in improving temperature-related health outcomes. These interventions include policies focused on income creation as well as heat early warning systems, heat action plans and improved temperature forecasts. Policymakers, government decision-makers, funders, and the general public can leverage the CIL Adaptation Inventory, a curated, updated source of rigorous studies demonstrating effective adaptation measures, to learn more about options to meet the needs of local communities as they seek to adapt to a warming climate.

Regional spotlights

Global organizations need to understand where to prioritize their efforts and funding across the world. However, many organizations have a more targeted geographic focus and can benefit from a regional[13] assessment of how climate change will shape energy demand and energy-based adaptation. These summaries provide a snapshot of the projected changes in electricity consumption for each continent and include countries of all income levels. With the main body of this report primarily focusing on where we project the smallest changes in electricity consumption and the implications for human welfare, here we highlight where some of the largest changes in consumption will occur within each continent as an indicator of where there may be stress to existing electricity markets and infrastructure. These areas may need to prioritize adjustments to their markets as well as enhanced resilience of electrical grids to adapt to increasing heat.

13 Regional definitions are consistent with those used by UN Statistics Division.

Guide to Visualizations

Maps: Change in region-level annual consumption (GJ/capita) of electricity in 2050 compared to the 2001-2010 average due to climate change. Positive values indicate an increase in consumption. Negative values indicate a decrease in consumption. Note that the color scales are custom to each continent such that continent maps should not be directly compared.

First chart: Countries with the largest increase in electricity consumption in 2050 when compared to current electricity consumption (%; left). Associated absolute changes in electricity consumption (GJ/capita) are shown on the right. The top 15 countries in each continent (where applicable) are shown. Only countries with available current consumption data from IEA (2025) are shown. Many small island nations are among those lacking current consumption data such that portions of the Caribbean and Oceania are likely to be underrepresented in this chart.

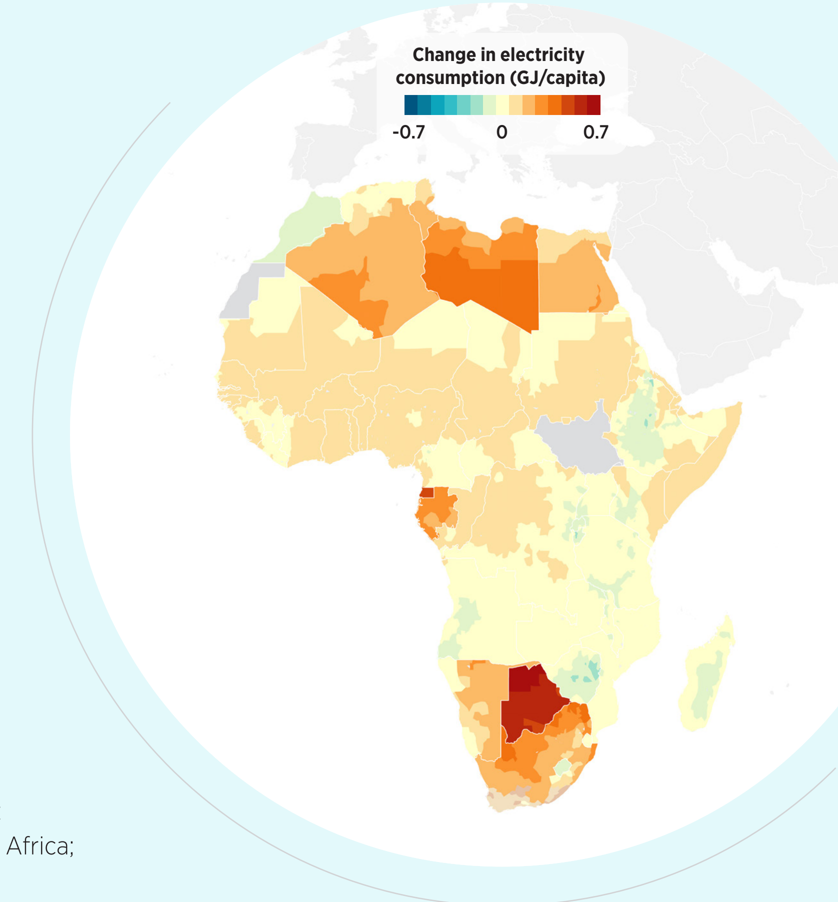
Second chart: Cities with current populations exceeding 500,000 with the largest increase in electricity onsumption in 2050 (GJ/capita)[14]. The top 15 cities in each continent (where applicable) are shown. Cities within 100km of each other are listed together.

14 City-level electricity consumption projections are provided as GJ/capita to facilitate their use by adaptation planners for their relevant operation areas and population projections.

REGIONAL SPOTLIGHT

Africa

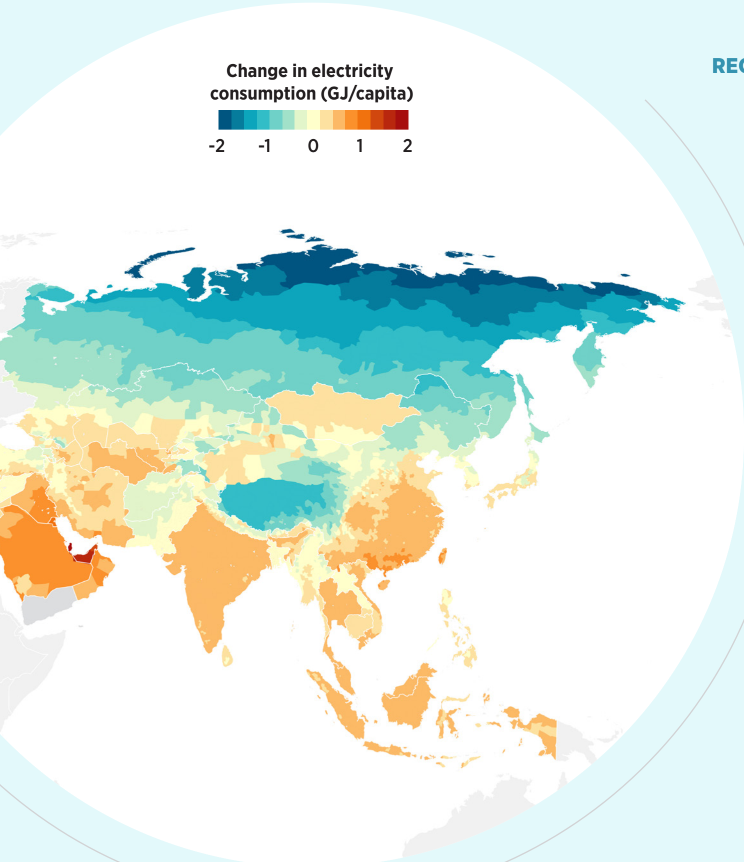
CIL projections indicate that most of the African continent will see modest absolute changes in electricity consumption for cooling; more than 90% of the regions in Africa are projected to see changes in electricity consumption below the global median (0.14 GJ/capita). In many African countries, however, that reflects a significant increase in consumption relative to current levels. Five countries across northern sub-Saharan Africa will see relative increases in electricity consumption in 2050 exceeding 20% of their current consumption, including Niger, Burkina Faso, Benin, and Nigeria. Chad is a stark example and will more than double its current consumption of electricity. These projections note both the financial constraints that will keep much of the continent from increasing electricity to adapt to heat as well as the need to establish resilient infrastructure and well-functioning electricity markets where they do not yet exist. Cities that will see the largest increases in electricity consumption and therefore may experience that infrastructure stress include Libreville, Gabon; Pretoria, South Africa; and Tripoli and Benghazi, Libya.



Country	Change in electricity consumption	
Chad	162%	0.07 GJ/capita
Niger	70%	0.07
Burkina Faso	28%	0.06
Benin	26%	0.07
Nigeria	23%	0.07
Equatorial Guinea	15%	0.46
Sudan	14%	0.08
Mali	12%	0.07
Botswana	12%	0.51
Togo	11%	0.06
Dem. Rep. of the Congo	9%	0.03
Republic of Congo	8%	0.07
Mauritania	6%	0.06
Gabon	6%	0.22
Cameroon	6%	0.04

City	Change in electricity consumption
Libreville, Gabon	0.23 GJ/capita
Pretoria, South Africa	0.22
Tripoli, Libya	0.19
Benghazi, Libya	0.18
Durban, South Africa	0.17
Port Elizabeth, South Africa	0.11
Giza/Cairo, Egypt	0.11
Djibouti, Djibouti	0.09
Omdurman/Khartoum, Sudan	0.08
Lagos, Nigeria	0.08
Accra, Ghana	0.08
Cotonou, Benin	0.08
Tunis, Tunisia	0.07
Alexandria, Egypt	0.07
Port Harcourt, Nigeria	0.07

*Cities near Pretoria and not listed separately are Vereeniging (0.16 GJ/capita), Johannesburg (0.13 GJ/capita), and Benoni (0.13 GJ/capita)



REGIONAL SPOTLIGHT

Asia

Most countries in Asia (45 of the 53 modeled) are projected to see increases in electricity consumption for cooling due to climate change in 2050 with the range of outcomes being driven by the continent's diverse income levels and climate. Due to relatively high levels of current consumption across the continent, just two countries, India and Iraq, are projected to see increases that exceed 10% of current consumption. Lebanon, Indonesia, and Cambodia follow with projected increases of 6-7% of current levels. These countries will be among those where increased demand may exacerbate stress on power markets and infrastructure that are already unstable and will therefore require continued development to support adaptation to heat via air conditioning. Some of the largest increases in consumption on absolute terms reside in the Middle East—10 of the 15 Asian cities with the largest projected increases in electricity consumption are in that region, including Doha, Qatar (1.6 GJ/capita); Abu Dhabi, United Arab Emirates (1.3 GJ/capita); and Manama, Bahrain (1.1 GJ/capita).

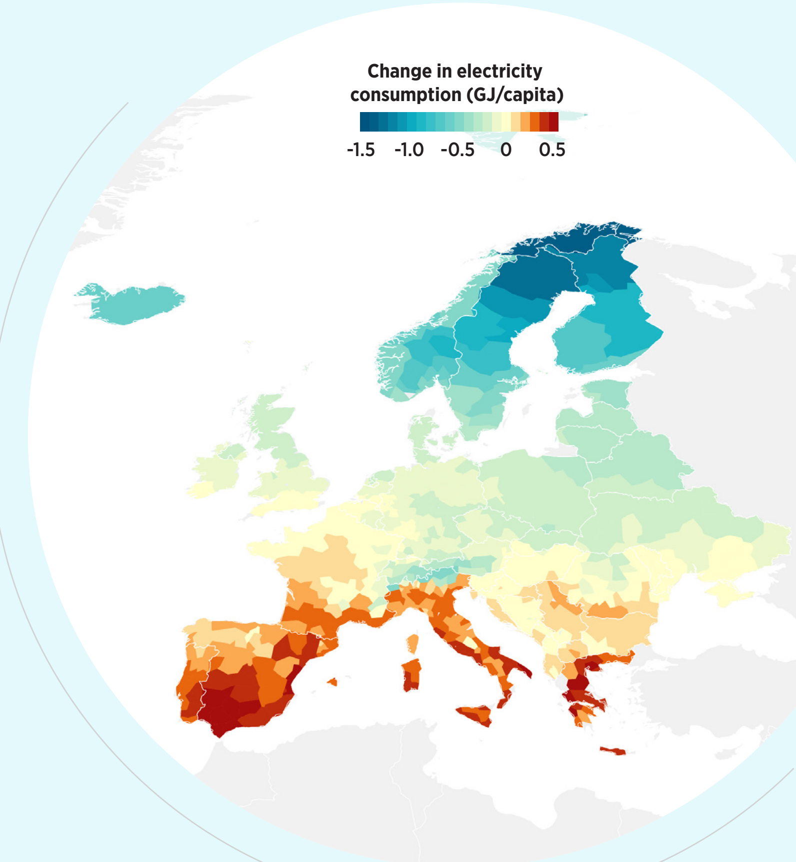
Country	Change in electricity consumption	
Iraq	17%	0.50 GJ/capita
India	12%	0.36
Lebanon	7%	0.20
Indonesia	6%	0.32
Cambodia	6%	0.16
Thailand	4%	0.43
United Arab Emirates	4%	1.23
Turkmenistan	4%	0.33
Azerbaijan	4%	0.25
Uzbekistan	4%	0.23
Cyprus	4%	0.39
Hong Kong	4%	0.62
Qatar	3%	1.59
Vietnam	3%	0.28
Saudi Arabia	3%	0.59

City	Change in electricity consumption
Doha, Qatar	1.59 GJ/capita
Abu Dhabi, UAE	1.26
Dubai/Sharjah, UAE	1.22
Manama, Bahrain	1.10
Kuwait City, Kuwait	0.84
Singapore	0.83
Medina, Saudi Arabia	0.70
Ad Dammam, Saudi Arabia	0.68
Riyadh, Saudi Arabia	0.66
Jeddah/Mecca, Saudi Arabia	0.62
Tainan, Taiwan	0.62
Hong Kong	0.61
Kaohsiung, Taiwan	0.61
Muscat, Oman	0.56
Guangzhou/Dongguan, China	0.56

REGIONAL SPOTLIGHT

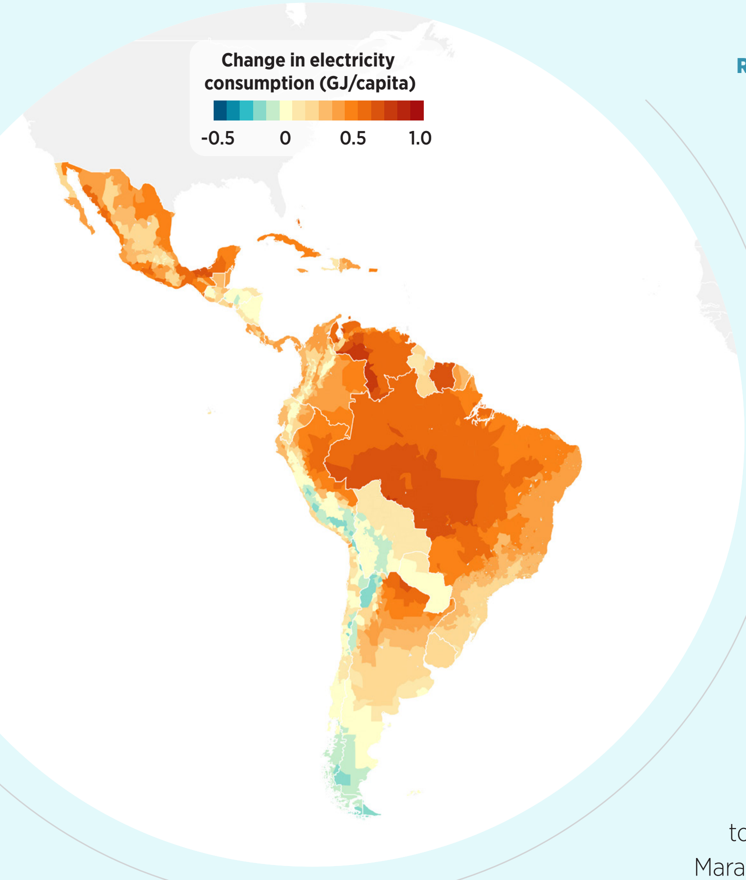
Europe

With less income diversity than some of the other continents, Europe's projected changes in electricity consumption are heavily driven by climate. The northern, cooler half of the continent will see declines in demand for heating that exceed any increased demand for cooling, resulting in net declines in electricity consumption. In the southern, warmer half of the continent, we project overall increases in electricity consumption, although those changes will be modest compared to current levels. Greece, Spain, and Malta are projected to see the largest increases in consumption relative to current consumption—just ~2%. Cities across the southern half of Europe that are projected to see increases in electricity consumption include Sevilla, Spain (0.5 GJ/capita); Athens, Greece (0.4 GJ/capita); Rome, Italy (0.4 GJ/capita); and Marseille, France (0.3 GJ/capita).



Country	Change in electricity consumption	
Greece	2.3%	0.35 GJ/capita
Spain	1.9%	0.29
Malta	1.8%	0.39
Portugal	1.4%	0.22
Italy	1.4%	0.23
Serbia	0.9%	0.10
Albania	0.7%	0.05
Macedonia	0.7%	0.06
France	0.4%	0.05
Croatia	0.3%	0.05
Bulgaria	0.3%	0.06
Gibraltar	0.3%	0.09
Montenegro	0.1%	0.01
Romania	0.1%	0.01
Bosnia and Herzegovina	0.1%	0.01

City	Change in electricity consumption
Sevilla, Spain	0.49 GJ/capita
Madrid, Spain	0.39
Athens, Greece	0.35
Rome, Italy	0.35
Naples, Italy	0.34
Barcelona, Spain	0.29
Marseille, France	0.25
Lisbon, Portugal	0.24
Milan, Italy	0.21
Turin, Italy	0.2
Florence, Italy	0.2
Porto, Portugal	0.18
Belgrade, Serbia	0.13
Bucharest, Romania	0.1
Lyon, France	0.1



REGIONAL SPOTLIGHT

Latin America and The Caribbean

Most of Latin America and the Caribbean will consume more electricity due to climate change compared to current levels; 46 of the 50 modeled countries are projected to see increased consumption to support cooling requirements by 2050. The countries of Suriname, the Bahamas, and Venezuela (0.6, 0.6, and 0.5 GJ/capita, respectively) are projected to see the largest absolute increases, while Haiti stands out as being projected to see the largest increase in consumption relative to current levels (28%). Following Haiti, Jamaica, Venezuela, and Cuba, are among countries projected to see the largest relative increase in electricity consumption (8-9%), all of which may see stress on their electrical grid as communities adapt to higher temperatures via cooling and where electricity market reform may be relevant. Numerous cities across the continent are projected to consume more electricity, including those in Venezuela (e.g., Maracaibo; 0.6 GJ/capita), Brazil (e.g., Manaus; 0.6 GJ/capita), Mexico (e.g., Torreón; 0.4 GJ/capita), and Cuba (Havana; 0.4 GJ/capita).

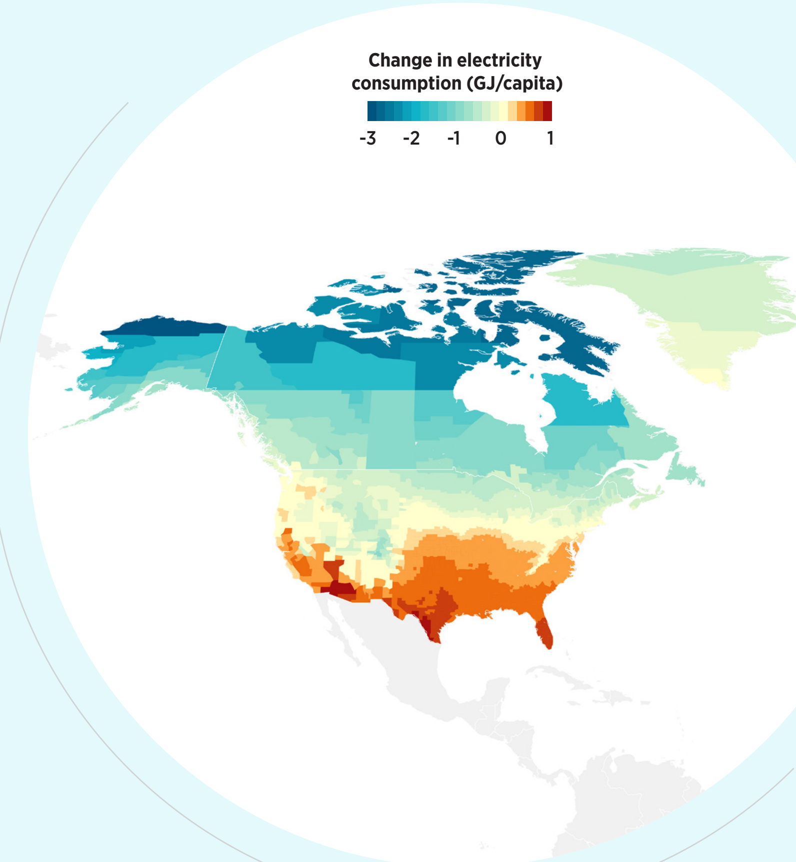
Country	Change in electricity consumption	
Haiti	28%	0.07 GJ/capita
Jamaica	9%	0.37
Venezuela	8%	0.45
Cuba	8%	0.43
Suriname	6%	0.57
Dominican Republic	6%	0.31
Guatemala	5%	0.09
Panama	4%	0.34
Colombia	4%	0.16
El Salvador	4%	0.16
Mexico	4%	0.28
Brazil	4%	0.32
Costa Rica	4%	0.21
Ecuador	3%	0.14
Peru	2%	0.13

City	Change in electricity consumption
Maracaibo, Venezuela	0.60 GJ/capita
Manaus, Brazil	0.59
Goiânia, Brazil	0.51
Belém, Brazil	0.48
Barquisimeto, Venezuela	0.48
Torreón, Mexico	0.44
Valencia, Venezuela	0.43
Havana, Cuba	0.42
São Luís, Brazil	0.41
Kingston, Jamaica	0.40
Vila Velha, Brazil	0.40
Monterrey, Mexico	0.39
Fortaleza, Brazil	0.39
Ciudad Juárez, Mexico	0.39
Brasília, Brazil	0.38

REGIONAL SPOTLIGHT

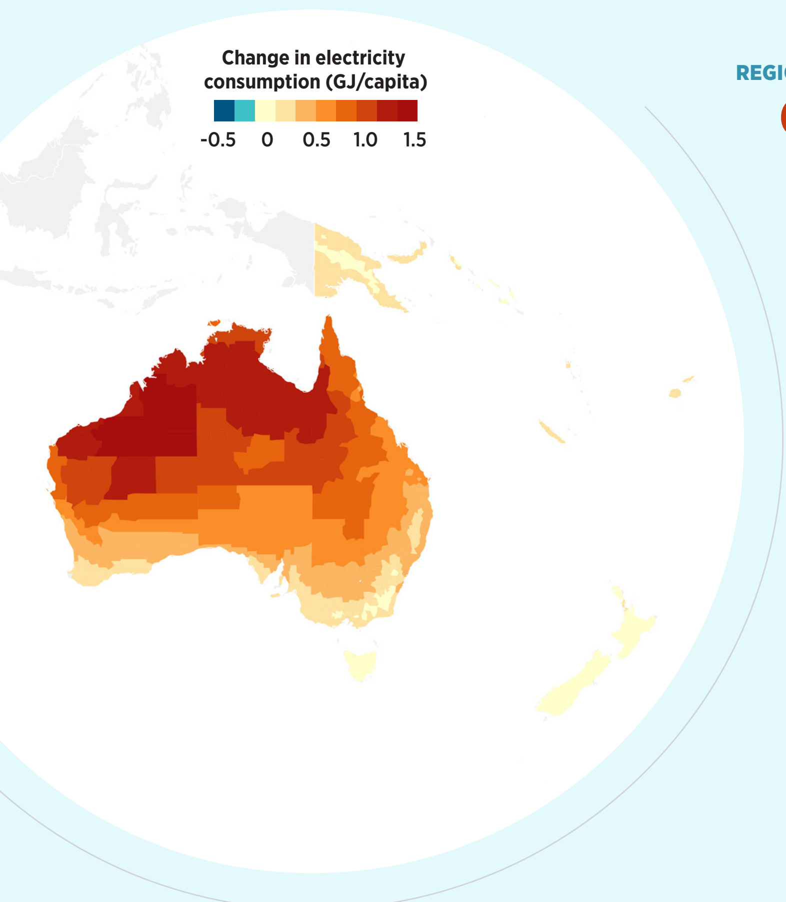
North America

CIL projects that in 2050, Canada will decrease its use of electricity due to a lower demand for heating as the climate warms (-0.9% of current consumption), while the southern half the United States will increase use of electricity due to higher demand for cooling. Countrywide, the United States will use 0.6% more electricity compared to current consumption. The more temperate areas of the northern U.S. and southern Canada may still see stress on their electrical infrastructure on a seasonal basis despite the net decline in consumption overall, as communities increase their consumption during summer months to adapt to higher temperatures. Urban areas that are projected to see the largest increase in demand for electricity reside along that southern tier of the U.S. Phoenix, Arizona will see the largest absolute increase in electricity consumption among large American cities (0.9 GJ/capita), with most of the remaining top cities residing in the states of California, Texas, and Florida.



Country	Change in electricity consumption	
United States	0.6%	0.22 GJ/capita
Greenland	-0.7%	-0.13
Canada	-0.9%	-0.38

City	Change in electricity consumption
Phoenix, United States	0.88 GJ/capita
San Antonio, United States	0.71
Austin, United States	0.67
Miami, United States	0.65
Las Vegas, United States	0.64
Tampa, United States	0.63
Orlando, United States	0.63
Dallas, United States	0.62
Houston, United States	0.60
Jacksonville, United States	0.54
New Orleans, United States	0.51
Riverside, United States	0.46
Memphis, United States	0.43
Sacramento, United States	0.41
San Diego, United States	0.37



REGIONAL SPOTLIGHT

Oceania

All countries in Oceania are projected to increase their consumption of electricity as the climate warms, including all of the island nations in the Pacific (not shown). Australia will see a modest uptick of 1.5% nationwide in 2050, with the largest increase in consumption occurring in the relatively less populated northern half of the country. The large cities along coasts, including Brisbane, Perth, Sydney, and Newcastle are projected to consume an additional ~0.4 GJ per person. CIL projects an even more modest increase of 0.3% compared to current electricity consumption in New Zealand (0.06 GJ/capita).

Country	Change in electricity consumption	
Australia	1.5%	0.33 GJ/capita
New Zealand	0.3%	0.06

City	Change in electricity consumption
Brisbane, Australia	0.43 GJ/capita
Perth, Australia	0.38
Sydney, Australia	0.38
Newcastle, Australia	0.37
Adelaide, Australia	0.26
Melbourne, Australia	0.20
Auckland, New Zealand	0.12

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The authors appreciate the contributions of Jennifer Agbo (University of Chicago) for her analytical support.

Part of the Energy Policy Institute at the University of Chicago (EPIC), the Climate Impact Lab's global network of economists, climate scientists, data engineers, and risk analysts are identifying where climate adaptations are most needed and what investments will deliver the greatest benefits to communities. This work builds off of a decade of research that projected the impacts of climate change globally and locally on mortality, agricultural productivity, labor supply, energy demand and coastal flooding risk. Published in the world's leading scientific and economics journals, the research formed the basis for the US Government's official estimate of the cost of climate change and has been used by the International Monetary Fund and Federal Reserve, private companies like Nike, Microsoft and Realtor.com, and the United Nations Development Programme.

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