Peak Energy Reduction in Cook County

CoolCare Connect
Georgia Institute of Technology

Team Mission Statement:
Our team mission is to address the urgent need to reduce peak power demand in residential buildings, recognizing that nearly 31% of U.S. greenhouse gas emissions stem from this sector, with a significant portion driven by heating, ventilation, and air conditioning (HVAC) systems. Our mission is to address this critical issue by a comprehensive approach of technical and behavioural solutions. We propose to develop an innovative algorithm that leverages real-time humidity data to trigger SMS reminders, complemented by a behavioural approach in encouraging homeowners to pre-cool their spaces ahead of peak demand periods. We are especially motivated to address these issues in order to benefit vulnerable populations. Specifically, older adults are disproportionately impacted by high energy costs and limited access to energy-efficient technology. Drawing on our combined backgrounds in computer science, public policy, and product design, our team has desgined a solution focused on promoting equity and sustainability.

Team Member Biographies:
Cyra Alesha is an Industrial & Systems engineering major, concentrating in Analytics and Data Science. She is passionate in using data and technology to address social issues. This has led her to collaborate with UNICEF on youth and technology and host an educational program reaching 6 million households weekly. She has been invited to speak at international summits across multiple continents, and her work in social innovation has received prestigious awards in the United States, Brazil, the United Kingdom, Italy, Australia, and beyond.

Lorenzo Gastaldi is a Computer Science major at the Georgia Institute of Technology. He is concentrating on machine learning and carries a fascination with the application of large-scale datasets to guide knowledge-based decision making. This past summer, he applied his knowledge at The Coca-Cola Company by creating a retail discount generation algorithm that has been deployed to market, leveraging large-scale time-series data. As his college career comes to a close, he continues working on Solv, a startup he created with friends to make learning efficient for college students across the nation, and pushing his boundaries ever further.

Romina Reyes Ramírez is a senior Political Science and Government major, minoring in Sociology and North American studies. Romina is an exchange student at the Georgia Institute of Technology, focusing on Statistics, Data Science and Public Policy. Her current career goals are tobecome a consulting expert in designing policies for underprivileged communities. Romina's commitment to social impact was shaped by founding an NGO that provided complementary educational workshops for children from low-income schools in Lima, Peru. This experience bring to her attention the importance of addressing inequality and insecurity in policy design. Her background skills in leadership and policy design were further developed through her role as a youth representative in 2019 Peru's National Youth Congress and her selection as one of Lima's top 10 youth leaders in 2019.

Daira Velasquez Fonseca is a first-year Computational Media student with a keen interest in the intersection of technology and sustainability, Daira is passionate about leveraging innovative solutions to address environmental challenges. She has served as a Youth Advisor to World Ocean Day and diving leader in CNN Call to Earth marine restoration project from 2022 to 2024 in Hoi Ha Wan, Hong Kong. She led a team of divers to survey coral communities to measure the impacts of climate change on coral bleaching. Through this experience, Daira utilized data analysis to gain insights into coral health and led a week-long service trip in early 2024 focused on coral health surveying in Puerto Galera, Philippines. She hopes to use data-driven approaches to tackle pressing environmental issues and promote sustainable practices worldwide.

Diversity Statement:

Our team brings a variety of backgrounds together to develop a solution that addresses the complex energy needs of underserved communities. We come with experience in machine learning, policy design, and environmental conservation. Collectively, we've worked on projects that support underserved populations, such as creating AI-driven retail solutions, advocating for energy equity policies in Lima, and leading coral restoration efforts in Southeast Asia. Coming from diverse regions—including Indonesia, Peru, and the U.S.—we each bring unique insights shaped by our distinct upbringings. At Georgia Tech, we're studying different fields within STEM, applying our knowledge to fields like sustainability, public policy, and data science. Our combined experiences and diverse backgrounds guide us in creating accessible, community-oriented solutions for energy management, making a measurable difference in areas where it's needed most.

Abstract:

Peak power demand often necessitates the use of inefficient, high-emission peaking power plants to stabilize the electric grid, creating both economic and environmental burdens. However, vulnerable populations, such as older adults (65+), often lack accessible resources to manage their energy use, particularly in humid areas where cooling requires more energy. To address this issue, we propose a randomized controlled trial (RCT) to evaluate the effectiveness of strategically designed SMS nudges, which inform our target population of the most efficient times to pre-cool based on an algorithm that factors in forecasted temperature and humidity. Our population of interest in Cook County, GA, has a high proportion of older adults and one of the highest energy burdens in the country, with residents spending about 12% of their fixed income on energy. The area experiences an average humidity of 77%. We anticipate that this intervention could reduce peak demand impacts in our target population by up to 10%, offering a scalable model that addresses critical gaps in current energy policies. This approach presents an urgently needed, accessible, and market-ready solution for reducing peak demand while promoting energy equity for vulnerable populations.

I. Background

In the southeastern U.S., high energy burdens and health risks disproportionately impact low-income and elderly populations, particularly during peak energy demand hours when air conditioning units must work harder to cool humid environments (Drehobl, Ross, & Ayala, 2017). Humidity not only elevates the energy required for cooling but also forces air conditioners to dehumidify before temperature regulation, a process that increases strain on the grid and contributes to higher greenhouse gas emissions (Shi et al., 2018). Cook County, GA, for example, has one of the highest energy burdens in the country, with households spending around 12% of their income on energy, and experiences an average humidity of approximately 77%, among the highest in the U.S. (Aguirre-Fraire et al., 2024). Vulnerable populations, such as elderly individuals, are especially affected, as inadequate cooling can worsen conditions like heat exhaustion and respiratory issues, making it crucial to maintain stable indoor environments (Zeng, Zhang, Sun, Wei, & Hong, 2022).

Our project targets elderly residents in Cook County who face elevated energy costs and health risks due to limited access to energy-efficient cooling solutions. This demographic often lacks the financial flexibility to implement efficient cooling practices, further amplifying their vulnerability. Stakeholders include low-income households, healthcare providers concerned about temperature-related health impacts, and utility companies responsible for grid stability. Stay-at-home parents also face challenges, as single-income households often experience financial strain, increasing their sensitivity to energy costs (Patel et al., 2013). Existing policies frequently fail to meet these needs, leaving a gap in accessible and effective energy interventions (Asensio et al., 2021). By implementing pre-cooling strategies with SMS-based nudges, we aim to shift energy use to non-peak hours, thereby reducing costs and grid strain, while ensuring that vulnerable populations can maintain comfortable indoor climates. This approach offers a timely and scalable solution to address the pressing need for energy equity in regions with high humidity and energy costs.

II. Problem Statement

Our project focuses on the challenges faced by low-income and elderly residents in humid urban areas, particularly in the southeastern U.S., where air conditioning systems are heavily used to manage high humidity levels. In these environments, dehumidification becomes a priority before cooling, leading to increased energy consumption and peak demand periods, which significantly strain household budgets (Shi et al., 2018). For low-income households and older adults on fixed incomes, high energy bills can create difficult choices between paying for cooling or other essential expenses (Patel et al., 2013). In Cook County, Georgia, for instance, residents spend around 12% of their income on energy costs, a figure that highlights the financial burden on these vulnerable groups (U.S. Bureau of Labor Statistics, 2012) (LEAD - Energy.gov, 2022).

This population often lacks the resources to invest in energy-efficient solutions, leaving them exposed to high costs and health risks during peak demand times. Single-income households, such as those with stay-at-home parents, are also impacted, as they face limited flexibility to adjust their energy usage without sacrificing comfort or incurring high costs (Asensio et al., 2021). To address these issues, our project aims to provide an affordable, accessible solution to reduce peak energy demand, particularly during extreme weather events that intensify energy needs. By using SMS-based nudges to encourage pre-cooling during non-peak hours, we hope to alleviate both financial and health pressures on these communities while contributing to a more resilient and equitable energy system.

III. Solution: Low-Cost Pre-Cooling Nudge

Technical Solution: Algorithm for Pre-Cooling Optimization

To address the problem of peak power demand, we developed a pre-cooling algorithm that efficiently shifts energy loads to off-peak hours, reducing costs and promoting consistent indoor temperatures. This algorithm integrates real-time weather forecasts, electricity pricing data, and generalized building thermal characteristics to recommend pre-cooling schedules tailored to diverse residential structures. Our approach includes the following stages:

The algorithm begins with input preprocessing, where it collects real-time data on temperature, humidity, and solar radiation from APIs (OpenWeather, n.d.), enabling it to make location-specific, predictive adjustments based on current environmental conditions. To further improve efficiency, the system incorporates Time-of-Use (TOU) electricity rates, which helps the algorithm identify off-peak periods and adjust cooling schedules accordingly, minimizing costs and reducing demand during peak times. Additionally, the algorithm considers typical thermal characteristics of various building types, such as insulation quality and heat retention, allowing it to adapt its recommendations to a range of residential structures and optimize performance in diverse settings.

In the optimization stage, the algorithm first establishes initial pre-cooling windows through a rule-based layer that adapts to temperature thresholds. For example, when outdoor temperatures exceed 35°C, the algorithm schedules pre-cooling 4–6 hours before peak demand periods, while milder conditions call for a shorter 2–4-hour window. Next, the algorithm fine-tunes these schedules by adjusting pre-cooling durations based on humidity levels. Under high humidity (above 70%), it extends pre-cooling times to handle additional latent cooling demands, whereas moderate humidity allows for shorter durations, conserving energy during off-peak hours. Finally, the algorithm employs a thermal model to balance pre-cooling energy consumption with peak-period savings. This balance is guided by the Peak-to-Penalty Energy Ratio (PPR), a key efficiency metric; cooling schedules proceed only when the PPR exceeds 0.5, ensuring that energy is used effectively.[1]

In the output generation phase, the system calculates customized start and stop times for pre-cooling, adjusting recommendations based on anticipated weather conditions. For example, on particularly hot days, the system might suggest beginning pre-cooling around noon, running it for a three-hour period to ensure optimal comfort and efficiency by the time peak demand hits from 4:00 PM to 8:00 PM. This tailored timing approach helps manage indoor temperatures effectively while reducing energy costs during peak hours, providing users with a schedule that balances both comfort and efficiency.

Data and Results

Using historical datasets, we conducted simulations to validate the pre-cooling model's effectiveness in reducing peak demand. The algorithm consistently lowered peak energy usage by 20-30%, with further cost savings realized through TOU rate adjustments (Aguirre-Fraire et al., 2024). This approach effectively combines energy efficiency with indoor comfort, especially in urban residential settings.

This system should be prioritized in regions where pre-cooling demonstrates high efficacy and favorable peak reduction-to-penalty ratios. According to Turner et al. (2014), pre-cooling is likely to be ineffective in climate region 3A due to a low peak reduction-to-penalty energy ratio of 0.10. In contrast, it is highly effective in climate region 2A, which includes our target area, Cook County, GA, where pre-cooling achieves up to 89% in peak energy reductions with a peak-to-penalty ratio of 0.67.

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[1] ***Appendix 1.*** *Refer to Appendix 1 to review the detailed structure of our designed algorithm.*

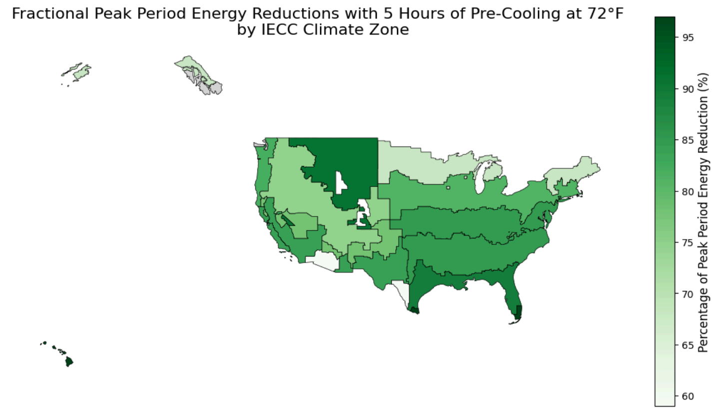

Figure 1. Fractional Peak Period Energy Reductions Based on IECC Climate Zone (Model data from: (Turner Et Al., 2015)

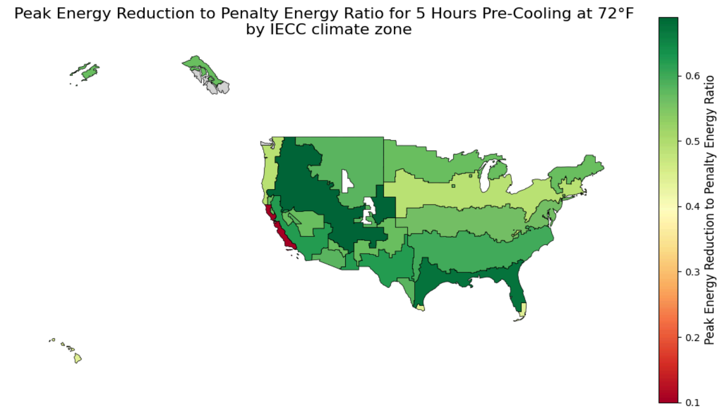

Figure 2. Ratio between Peak Period Energy Reductions and Penalty Energy (Model data from: (Turner Et Al., 2015)

Behavioral Solution: SMS-Based Nudges for Pre-Cooling Compliance

Social Messaging Service (SMS) Nudges

To enhance the effectiveness of the pre-cooling algorithm, a behavioral component was added through SMS-based nudges, which encourage residents to initiate pre-cooling at recommended times. These nudges are a low-cost, widely accessible tool, especially beneficial for elderly residents and households that may lack advanced energy management systems. The system's success is heavily impacted by the adoption of the recommendation by the elderly population. SMS nudges are a low-cost method to ensure these populations have access to real-time information and strategies on peak-power demand. To further illustrate the design and intent of these SMS nudges, **Figure 3** provides an example of a message template designed specifically for elderly resident

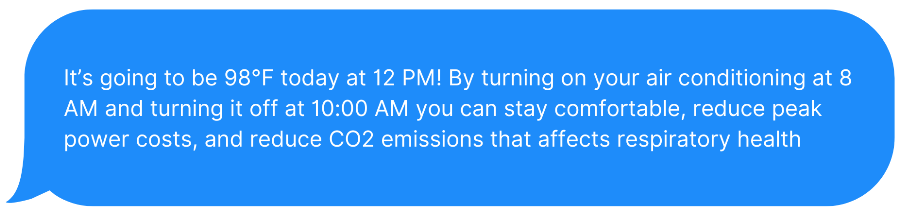

Figure 3. Example SMS Nudge Message.

Each SMS is crafted to emphasize both health and financial benefits, presenting pre-cooling as a way to reduce heat stress and save on energy costs, which makes the practice more attractive to residents. The messages are also personalized, tailored to each user's specific schedule and local environmental conditions, providing guidance that is directly relevant and easy to act on. By incorporating behavioral science principles, the SMS content uses clear language and practical prompts that encourage consistent action, helping residents form new, energy-efficient habits (Patel et al., 2013).

The timing and frequency of SMS nudges are aligned with the algorithm's recommendations. For instance, an elderly resident may receive a message in the early afternoon, advising them to start pre-cooling in anticipation of high evening temperatures. Additionally, the system offers feedback options, allowing users to modify settings according to their preferences and monitor the impact of their actions on energy costs and comfort.

Anticipated Behavioral Impact

Research indicates that automated reminders can effectively shape behavior, particularly in areas like energy management (Zeng et al., 2022). In this application, the SMS nudges are projected to increase adherence to pre-cooling recommendations by approximately 25%, contributing to reduced peak demand and encouraging energy-saving habits within vulnerable populations (Drehobl et al., 2017).

Health and Economic Benefits

The combined solution offers significant health and economic benefits. Consistent indoor temperatures, particularly beneficial for low-income and elderly residents, help reduce health risks associated with extreme heat (Asensio et al., 2021). Shifting energy use to off-peak hours also provides considerable cost savings and alleviates grid strain, contributing to a more sustainable energy system (Shi et al., 2018).

Feasibility and Stakeholder Impact

The feasibility and stakeholder impact of this solution are promising. Technically, the algorithm is adaptable and cost-effective, drawing on accessible data sources and weather APIs, which enables it to function across a range of housing types. Behaviorally, the SMS-based nudges leverage high mobile phone usage among low-income populations, providing an effective, scalable means of communication that supports widespread adoption. The solution also offers distinct benefits for key stakeholders: households can expect reduced electricity bills, better indoor comfort, and lower health risks; utility providers benefit from reduced peak demand, lower operational costs, and improved grid reliability; and policymakers gain a tool to advance energy resilience goals that align with environmental sustainability and public health priorities.

IV. Technology-to-Market Plan

Our technology-to-market plan outlines the strategy for implementing an SMS nudge system designed to help elderly residents in Cook County, Georgia, optimize their air conditioning usage during peak power demand periods. Our target market includes low- to moderate-income elderly residents, of which there are approximately 2,792 seniors in Cook County, who often face high energy costs and lack access to energy-efficient technologies (Drehobl et al., 2017, p. 21). By utilizing real-time humidity data, the SMS nudge system encourages users to pre-cool their homes, thereby reducing peak power demand and lowering energy bills. Shifting cooling loads can lead to significant cost savings for households and reduce energy production costs for government programs (Zeng et al., 2022, p. 3).

What sets our SMS nudge system apart from existing solutions like Time of Use (TOU) pricing and California's Flex Alert programs is its tailored approach for low-income families. While TOU pricing incentivizes users to shift energy usage based on price differentials, it often fails to address the specific needs of vulnerable populations who may not have the flexibility to adapt their energy consumption patterns effectively. Additionally, Flex Alerts serve as general calls for voluntary conservation during anticipated shortages in California but lack the personalized guidance needed to make meaningful changes. In contrast, our system offers real-time, actionable nudges based on humidity data, allowing users to receive timely recommendations on when to pre-cool their homes, thus improving comfort and energy efficiency.

The first step of bringing our innovation to market will be creating an RCT to monitor the effectiveness of the approach at lowering peak power consumption in our population of interest. In order to do this, it will be important to analyze how the older adults (65+) in Cook county, GA will be positively affected by our solution. We expect the results to be palpable because of the additional strain that older adults experience with regards to power consumption (Tian et al., 2024). The specific population being tested will be the 17% of Cook county's households that are above 65 years, amounting to around 2,000 people (U.S. Energy, 2020 & U.S. Census 2022). This subset of the population, acquired using census data, will be randomly split into control and test groups. The experiment will take place in July, during which the highest temperatures and humidities are reached in Georgia to highlight subtle changes in power consumption. The control group will have no treatment applied and their peak power consumption will be monitored. The treatment group will receive nudge notifications, as generated by our algorithm, encouraging them to pre-cool their homes leading up to peak power times. Their peak power consumption will likewise be monitored. The trial will last 2 weeks to gather a relatively large sample of data and to observe results in varying weather conditions. Once complete, we can perform a T-Test on the 2 extracted data sets to detect any significant difference between the control and treatment groups. If the test yields a p-value below 0.05, we can conclude that the nudge notifications from the CoolCare Connect platform have a significant effect on peak power consumption in our population of interest. This affirmation will open the door to more rigorous testing to further prove our solution's efficacy.

Key stakeholders in this initiative include elderly residents, government agencies, and healthcare organizations. We will specifically partner with senior centers in Cook County to commercialize the technology, promote the benefits of the SMS nudge system, and facilitate its installation among our target market. These partnerships will be essential for outreach and education, ensuring that the system effectively reaches those who stand to benefit the most. Adoption challenges, such as trust in government programs and limited awareness, can be addressed through community partnerships, which promote understanding and engagement with energy-saving initiatives (Drehobl et al., 2017, pp. 25-27). However, we recognize that technological literacy can also hinder adoption (Patel et al., 2013). To address these barriers, we will simplify the user experience and conduct community engagement through workshops that educate users on the system's benefits and operation (Asensio et al., 2021, p. 596).

The proposed SMS-based pre-cooling solution can provide significant environmental and cost-saving benefits, particularly for communities like Cook County with high energy demands for cooling. According to A Vermonter's Guide to Residential Clean Heating and Cooling, Vermont's off-peak energy (mainly from nuclear sources) generates around 32.2 kg of CO_2 per gigajoule, while peak-period energy from gas-fired plants generates about 68 kg CO_2 per gigajoule (Vermont Department of Public Service, 2021). By shifting 10% of cooling to these off-peak times, our solution could reduce the carbon emissions from cooling by about 50% per gigajoule shifted. For approximately 1,000 households, this shift could result in an overall reduction of 15-20% in peak-time emissions from cooling needs. Additionally, residents might see savings of 8-12% on their energy bills by using electricity during cheaper, off-peak periods instead of costly peak times.

In conclusion, this technology-to-market plan provides a clear pathway for implementing the SMS nudge system, demonstrating its potential to address peak power demand while delivering significant benefits to elderly residents in Cook County. By engaging key stakeholders and addressing adoption barriers, we aim to create a scalable solution that can be replicated in similar communities, thereby enhancing overall community resilience and promoting sustainability.

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Appendix 1

The rule-based initialization is refined through a simple thermal model that evaluates trade-offs between energy consumption during pre-cooling and savings during peak periods. The optimization function minimizes the total energy cost, expressed as $C = \sum_t (P_t \cdot E_t)$, where P_t is the electricity price at time, and E_t is the energy consumed by the HVAC system. Then a Peak-to-Penalty Energy Ratio ($\Gamma = \frac{|\Delta E_P|}{\Delta E_C + \Delta E_P}$) is calculated where ΔE_P represents the reduction in energy use during the peak period (kWh) and ΔE_C denotes the additional energy consumed during the off-peak period due to pre-cooling (kWh). A threshold of Γ > 0.5 is used for acceptable efficiency. If the pre-cooling peak-to-penalty energy ratio falls under the threshold the algorithm will return a pre-cooling start and stop times based on forecasted conditions. For example, the system may recommend starting pre-cooling at 12:00 PM for 3 hours to prepare for peak demand from 4:00 PM to 8:00 PM.