Metropolitan
ENERGY CENTER

The Impact of a Weatherization Program on the Health Outcomes for Children with Asthma

A Preliminary Study Commissioned by the City of Kansas City, Missouri, and Metropolitan Energy Center

Neal Wilson PhD, UMKC CEI; Claude Aloumon, UMKC CEI; Linwood Tauheed PhD, UMKC CEI; Kevin Kennedy, MPH, Children's Mercy Kansas City

June 2023

About the Study

Origins and Acknowledgment of Contributors

This preliminary study was commissioned by Metropolitan Energy Center (MEC), a Kansas City-based nonprofit, under a project funded by the City of Kansas City, Missouri. The project, EnergyWorks KC – Energy Solutions Hub, supports MEC's regional technical assistance hub for energy efficiency, building performance and healthy homes. The study confirms what both energy efficiency and health practitioners have known from experience for many years. However, it is only a first step in honing our knowledge of the most cost-effective home modifications that may help protect its occupants.

The germ for this research came about due to previous work and research of the Children's Mercy Kansas City (CMKC) Healthy Home Program, where hospital staff witnessed positive health outcomes with many of their young asthma patients whose families had enrolled in the program and received healthy home education, resources and repairs. Through these services, CMKC and similar programs around the country have seen significant positive outcomes for asthma patients when the home indoor environment is improved.

Weatherization is a building upgrade process that keeps indoor air in and outdoor air out. A good weatherization upgrade keeps you safe and comfortable in your home, no matter what the weather is doing. For nearly a decade, MEC administered weatherization and energy efficiency renovations under various partnerships, including the City of Kansas City, Missouri's EnergyWorks KC (EWKC) project.

This research partnership with MEC, CMKC and the Center for Economic Information at the University of Missouri Kansas City (CEI) brought even bigger data to the table for a more comprehensive picture of potential health improvements.

MEC would like to thank all of the partners mentioned above who made this study possible.

About KC Health CORE

KC Health CORE is a data sharing collaborative between the Environmental Health Program at Children's Mercy Kansas City and the UMKC Center for Economic Information. The collaborative received important financial support from HUD's Office of Lead Hazard Control and the Health Forward Foundation of Greater Kansas City.

About Children's Mercy Kansas City

Founded in 1897, Children's Mercy is a leading independent children's health organization dedicated to holistic care, translational research, educating caregivers and breakthrough innovation to create a world of well-being for all children. With not-for-profit hospitals in Missouri and Kansas, and numerous specialty clinics in both states, Children's Mercy provides the highest level of care for children from birth through the age of 21. U.S. News & World Report has repeatedly ranked Children's Mercy as one of "America's Best Children's Hospitals." For the fifth consecutive time in a row, Children's Mercy has achieved Magnet nursing designation, awarded to only about 8% of all hospitals nationally, for excellence in quality care. More than 850 pediatric subspecialists, researchers and faculty across more than 40 subspecialties are actively involved in clinical care, pediatric research and education of the next generation of pediatric subspecialists. Thanks to generous philanthropic and volunteer support, Children's Mercy provides hope, comfort and the prospect of brighter tomorrows to every child who passes through its doors. Visit Children's Mercy and the Children's Mercy Research Institute to learn more, and follow us on Facebook, LinkedIn, Twitter, Instagram and YouTube for the latest news and videos.

About Metropolitan Energy Center

MEC is a nonprofit based in Kansas City, Missouri, that is dedicated to creating resource efficiency, environmental health, and economic vitality in the Kansas City region. MEC works in built environments and transportation systems to improve energy efficiency and energy usage practices. MEC offers technical assistance, information and education to improve the health and wellness of all people who occupy the buildings, roads and outdoor spaces affected by emissions in the Kansas City region. From advocacy about energy technologies to coordination of energy-related workforce development opportunities, MEC commits to connecting promising energy efforts to the best resources available, until our region realizes a completely clean-energy society. MEC has been doing this work in cooperation with area nonprofits, municipalities, community organizations and businesses since 1983.

About EnergyWorks KC

The City of Kansas City launched EnergyWorks KC in 2010 to amplify its energy efficiency efforts. EWKC adopted a regional approach to residential and commercial upgrades, initially focused on six neighborhoods and the city's Green Impact Zone. The program raised local awareness and capacity for energy upgrades and laid the groundwork for a long-term shift toward improved energy performance in the region.

A Project Commissioned by the City of Kansas City, Missouri and Metropolitan Energy Center

June 18, 2023

The Impact of a Weatherization Program on the Health Outcomes for Children with Asthma

by

Neal Wilson PhD, UMKC CEI
Claude Aloumon, UMKC CEI
Linwood Tauheed PhD, UMKC CEI
Kevin Kennedy, MPH, Children's Mercy Kansas City

Thanks

The Center for Economic Information and Children's Mercy Kansas City would like to thank HUD's Office of Lead Hazard Control and Healthy Homes and the Health Forward Foundation of Greater Kansas City for their financial support of the work to develop the data repositories that were used in completing this project. We'd also like to thank Dr. Stephen Simon for statistical advising, Terry Kemper and Tim Kemper for discussing the implementation of the EWKC program, and our partners at Metropolitan Energy Center for sharing paper records from the EWKC project implementation, for sharing their subject matter expertise and clarifying our questions about the raw data. Finally, we'd like to thank the Office of Environmental Quality at the City of Kansas City, Missouri for providing the funding to perform the work for this project.

Acknowledgement and Disclaimer

Acknowledgment: This material is based upon work supported, in whole or in part, by the Department of Energy – Office of Energy Efficiency and Renewable Energy under Grant Award Number DE-EE0000758 from the Energy Efficiency and Conservation Block Grant Program made available pursuant to the American Recovery and Reinvestment Act (RECOVERY ACT) of 2009.

Executive Summary

The Center for Economic Information (CEI) at the University of Missouri Kansas City (UMKC) and Children's Mercy Kansas City (CMKC) were contracted to investigate the impact of the energy efficiency improvements initiated by the EnergyWorks KC (EWKC) project on health outcomes. The health outcome we studied was pediatric asthma among patients residing in homes that received energy efficiency improvements.

Our observational analysis finds that the EWKC program reduced the frequency of pediatric asthma encounters for those children diagnosed with asthma residing in homes that received energy efficiency improvements. Our preliminary statistical analysis finds that the EWKC program reduced the frequency of acute care pediatric asthma encounters, or acute care visits (ACV) among children with asthma residing in homes that received energy efficiency improvements.

To analyze the impact of the EWKC program on asthma outcomes for pediatric patients the CEI was provided energy efficiency improvement data by Metropolitan Energy Center (MEC). MEC data included information about all energy efficiency improvement activities administered between 2009 and 2013 through the Home Performance with Energy Star (HPwES) program. Encounter level historic pediatric asthma data was provided by CMKC (Housing and Health IRB protocol #11120500). Additional geographic and census data were sourced from the CEI data archives. Taken together, the CMKC and MEC data were sufficient for the task of describing the impact of EWKC weatherization actions on the health outcomes of pediatric asthma patients.

The structure of the EWKC program and its relationship with pediatric asthma is an example of a natural experiment. The research design can be considered 'as-if randomized', it overcomes the bias and endogeneity complaints that are typically associated with observational research. We considered an improvement in asthma along two axes, the frequency with which the asthma encounters occur, and their severity when they do occur. To reach our conclusions we accounted for the age of the home and whether it was located within Kansas City, Missouri.

Overview of our Analysis

The Center for Economic Information (CEI) at the University of Missouri Kansas City (UMKC) and Children's Mercy Kansas City (CMKC) were contracted to investigate the impact of the energy efficiency improvements initiated by the EnergyWorks KC (EWKC) project on health outcomes. The health outcome we studied was routine and acute care pediatric asthma visits among children living in homes served by the project. The EWKC project was a multifaceted program, and we do not attempt a thorough going summary here (A comprehensive description of the program is available online[1]). EWKC leveraged funding from the American Recovery and Reinvestment Act of 2009 (ARRA). The project spent $20,446,039 on the energy efficiency improvements between January 2011 and the January 2014. Weatherization activities were facilitated by utility company rebates of up to $2,000, subsidies up to $500 to cover the cost of energy audits, and eligibility for zero interest loans up to $15,000 (each figure is per single family home). The geographic focus of the EWKC project was Kansas City, MO, with particular emphasis on the Green Impact Zone, six targeted residential neighborhoods and one targeted commercial district.

To analyze the impact of the EWKC program on pediatric asthma we were provided energy efficiency improvement data by Metropolitan Energy Center (MEC) and historic asthma data from Children's Mercy Kansas City (CMKC). All home addresses provided by MEC were located in Missouri.

Encounter level asthma data was provided by CMKC and is maintained in a retrospective health database administered by CMKC for performing research on the relationship between different types of housing and community data and health encounters for different health conditions (Housing and Health IRB protocol #1125000E). The retrospective Asthma data are comprised of 67,698 asthma observations including routine and acute care visits (here after referred to as encounters) corresponding to 20,135 patients. The patient population was further limited to the pediatric population (under 16, n=17,550). All asthma encounters used in this analysis were located in Missouri. The study period was between 2009 and 2013. Most of the patients in the dataset are associated with more than one asthma encounter. These asthma data include approximately 93% of the hospitalizations for the patients whose data was used in the

[1] "American Housing Survey (AHS) - AHS Table Creator."

analysis and that took place in the Kansas City metropolitan area during the study period. (CMKC HIDI Data 2009 - 2015)

It is important keep in mind the scale on which Americans experience asthma, its costs in human terms, and its unequal distribution among the population. Every asthma attack is a frightening experience, a person struggling for a breath. Ten Americans die every day from asthma. Black Americans are 2-3 times more likely than any other racial or ethnic group to die from asthma because they were exposed to something (pollution, particulate, allergens, airborne chemicals, extreme weather and other triggers) that led to a flare-up or attack causing their airways to constrict and preventing exhalation. Fortunately, there are effective medicines to open airways and established disease management practices, but the number people who have this chronic respiratory disease is staggering. According to the US Centers for Disease Control and Prevention[2] 1 in 12 children and 1 in 13 adults in the US have asthma (26 million Americans). On an annual basis there are 439,000 hospitalizations from asthma, 1.7 million emergency department (ED) visits from asthma and 13.8 million days of school missed because of asthma. Each year there are about $50 billion in health care costs from asthma.

Data provided by MEC includes information about all energy efficiency improvement activities administered under the existing Home Performance with Energy Star (HPwES) umbrella. The HPwES program was contractually limited to addresses in Missouri, and EWKC was further limited to Kansas City, MO. Throughout this document we use the term weatherization as a shorthand for energy efficiency improvements. MEC provided address level information for 6,029 home weatherizations that took place between January 2009 and January 2014. Of these encounters, 2,719 were associated with the EWKC program. There was no significant difference between the energy audit, the weatherization work done, or the qualifications for inclusion in EWKC versus the other HPwES programs. Including both EWKC and HPwES weatherizations increased the strength of our analysis providing more heterogeneity in the housing stock in terms of location, housing type, and age of housing.

We used a geographic information system to match asthma encounters with the addresses of homes receiving energy efficiency improvements. Geographic and census data were collected as part of an initiative supported in part through grants from HUD's Office of Lead Hazard Control and Healthy Homes and the Health Forward Foundation of Greater Kansas City. Our match

[2] Centers for Disease Control and Prevention.

process found 881 encounters of 317 asthma patients. We were able to further subdivide this data into 549 encounters of 207 asthma patients at an MEC provided address before the weatherization took place and 318 encounters of 152 asthma patients at an MEC provided address after the weatherization took place. Forty-four asthma patients are associated with an asthma encounter at an MEC provided address before and after the weatherization activity took place. Fourteen of MEC encounters are not included in our analysis due to data quality issues.

Taken together, the CMKC and MEC data were sufficient for the task of describing the impact of EWKC weatherization actions on health outcomes for pediatric asthma patients.

Our analysis takes advantage of the disconnection between the focus of the EWKC program —a free weatherization rebate program—and the outcome we are measuring, health encounters associated with pediatric asthma. Although it fits with our intuition that weatherization would have an impact on pediatric asthma outcomes[3]—asthma can be triggered by atmospheric pollution and other outdoor airborne contaminants[4]; weatherization isolates the interior of the home where children spend most of their time from the exterior air contaminants—the EWKC program's aim was to improve energy efficiency and not health outcomes associated with pediatric asthma. The asthma status of children was not a selection criterion for the EWKC project, nor for the other weatherization programs administered by MEC. Impacts from the MEC programs in terms of asthma encounters reductions were unintentional secondary effects. This structure set up a natural experiment which allowed us to quantify the effect of weatherization on pediatric asthma.

The MEC administered programs in-effect randomly sampled from the population of pediatric asthma patients.[5] This sampling process allows us to make a stronger case for causality than is typically permitted in regression analysis. The research design was focused on the secondary benefits of asthma encounter reduction and overcomes the endogeneity complaints typically associated with observational research.[6]

We considered an improvement in asthma outcomes along two axes, the frequency with which the asthma encounters occur, and their severity when they do occur. Thus, we can fairly

---

[3] Johnson et al., "Low-Cost Interventions Improve Indoor Air Quality and Children's Health"; Ton, Rose, and Marincic, "Cascading Benefits of Low-Income Weatherization upon Health and Household Well-Being."
[4] Pope and Dockery, "Health Effects of Fine Particulate Air Pollution"; Jerrett et al., "Long-Term Ozone Exposure and Mortality."
[5] De Vocht et al., "Conceptualizing Natural and Quasi Experiments in Public Health."
[6] Craig et al., "Natural Experiments."

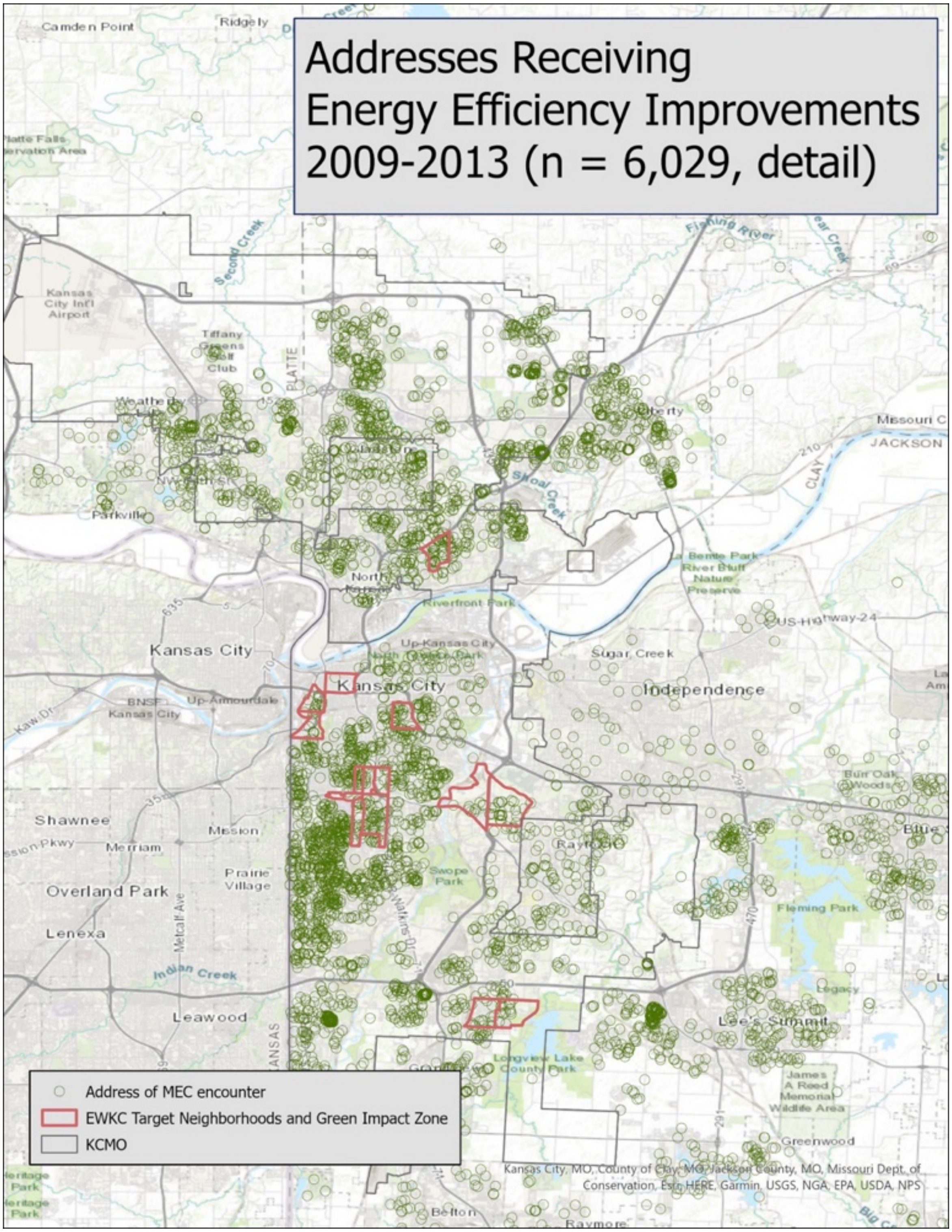
say that the weatherization programs administered by MEC, of which Energy Works Kansas City was an exemplar, made an improvement on health outcomes for pediatric asthma patients if we can demonstrate that a) children in weatherized homes had fewer asthma encounters which required medical attention than they otherwise would have and/or b) children in weatherized homes had less severe asthma encounters than they otherwise would have. Our preliminary analysis finds both to be the case.

Geography of MEC Data

The first step in our analytical process was to geocode each of the weatherization events supplied by MEC to the street-center line geography. After completing the geocoding process, we mapped these MEC encounters (Figure 1). Highlighted in Figure 1 are the six residential neighborhoods and the one commercial district, as well as the neighborhoods within which the Green Impact Zone was situated. These highlighted areas received special attention as part of the program to encourage participation in those places. Figure 1 is focused on Kansas City and does not symbolize the complete geographic extent of the weatherization events we geocoded. Although we were given all the EWKC addresses, they were combined in the data with the other homes that received energy efficiency upgrades from MEC. We were not able to authoritatively differentiate between the EWKC homes and the other homes in the data, as a result we do not symbolize the EWKC addresses separately from the other MEC addresses. Each small green circle in Figure 1 represents a different MEC address.

Table 1 illustrates the residency status by municipality across three data sets: the complete set of asthma encounters (Asthma Encounters), the complete set of MEC address data (MEC Address), the subset of asthma encounters associated with an MEC address (Asthma Encounters at MEC Address). Table 1 is truncated to show only the 10 municipalities with the most asthma encounters at an MEC address. The complete table containing counts for all 45 cities in included in Appendix A. We can see by inspection that Kansas City had the most observations across all three datasets. The data contains observations from several types of municipalities (cities, suburbs, and small towns) located throughout the Missouri side of the

Figure 1: Map of MEC Addresses



metropolitan area. We account for this heterogeneity in our statistical analysis by introducing two variables, one indicating age of housing construction and one indicating if the street address was located within Kansas City MO.

Table 1: Encounters per City: Three Principal Datasets

City	Asthma Encounters at MEC Address[1]	MEC Address[1]	Asthma Encounters[1]
KANSAS CITY, MO	257	3,862	12,269
LIBERTY	14	396	455
LEES SUMMIT	12	525	1,109
UNKNOWN	10	651	243
RAYTOWN	7	96	866
BLUE SPRINGS	4	175	768
INDEPENDENCE	3	80	1,962
SMITHVILLE	3	26	150
GRAIN VALLEY	2	11	223
NORTH KANSAS CITY	2	16	101
11..44			
WOOD HEIGHTS	0	NA	2

[1] Counts normalized by Medical Record Number to prevent double counting of patients

We used our geocoded data to drill down into the distribution of encounters within the Kansas City, MO. Table 2 reports the percentage of children at an MEC address and the percentage of MEC addresses within each KCMO council district. Compared with the frequency of MEC addresses there were relatively more asthma encounters associated with city council district 3 and 5, and fewer asthma encounters in council districts 2 and 4. These frequencies were consistent with the relative prevalence of asthma among the population of these districts. The figures in Table 2 are based on the Kansas City city council districts drawn after the 2010 census as being most reflective of the EWKC project. Appendix B contains a map of the council district geography and MEC encounters.

Table 2: Asthma at an MEC address per KCMO City Council District

City Council District	% Patients at MEC Address[1]	% MEC Address[1]
Kansas City, MO - Council District 1	16.7%	18.8%

Kansas City, MO - Council District 2	7.8%	17.7%
Kansas City, MO - Council District 3	30.4%	12.8%
Kansas City, MO - Council District 4	8.9%	13.7%
Kansas City, MO - Council District 5	17.5%	12.1%
Kansas City, MO - Council District 6	18.7%	25.0%

[1] Percentages are of encounters at a KCMO address as reported in row 1 of Table 1

Address Level Characteristics

To better understand the data and check for bias that may emerge in the geocoding process we looked at the address level characteristics of the data starting with the occupancy status of the resident of the home receiving and energy efficiency upgrade. The EWKC project was not limited to single family housing. About 10% of the homes in the program were multi-family homes. That ratio was not consistent for the asthma encounters at MEC address sample, the rate of multi-family homes among these data was about half that of the MEC addresses. According to the 2011 American Housing Survey 76% of the homes in the Kansas City metropolitan area are single family homes.

Table 3: Housing Type by Data Set

Type of Home	Asthma Encounters at MEC Address[1]	MEC Address[1]
Multi Family	5.10%	10.10%
Single Family	94.60%	89.80%
NA	0.40%	0.10%

[1] Percent normalized to prevent double counting of patients

Table 4 illustrates total amount spent by dataset. The mean amount of total spending on weatherization was about $250 less (10%) among the addresses with an associated asthma encounter than was the case for the total MEC data set. The median value of the amount spent on weatherizing an address with an associated asthma encounter was about $100 (about 6%) less than was the case for the total MEC data set. The distribution of the amount spent on weatherization was highly skewed for both data sets, as is expected for spending data. The maximum about spent in the complete MEC dataset was almost three times higher than the maximum amount spent at an address with an associated asthma encounter ($60,777 to $20,994). This longer upper tail of the distribution for MEC addresses explains some of the difference in mean values. Those addresses which received the minimum amount of spending typically spent $200 on an energy audit and $50 on duct sealing.

Table 4: Distribution of Total Spending by Dataset ($)

	Observations	**Mean (sd)**	**Median**	**Min**	**Max**
MEC Address	6,020	2,454 (2,945)	1,623	250	60,777
Asthma Encounters at MEC Address	256	2,207 (2,224)	1,525	250	20,994

Every home in the MEC dataset went through the same audit process to identify the work that needed to be done. Table 5 reports the distribution of this spending by dataset. The cost of a weatherization audit was related to the size of the home, larger homes being more expensive to audit. To some degree, the cost of an energy audit can be used as a proxy for size of the home. However, to ensure that weatherization funds were directed to paying for weatherization activities and not soaked up in other places, the EWKC program limited the amount it would pay towards an audit to $500. It is unsurprising that the mean amount spent on a weatherization was separated by less than $8 for the MEC addresses and the asthma encounters at MEC addresses. Note that MEC data were missing 73 address level observations of audit cost, and the asthma encounters at MEC data were missing two observations of audit cost.

Table 5: Distribution of Spending on Audit by Dataset ($)

	Observations	**Mean (sd)**	**Median**	**Min**	**Max**
MEC Address	5,956	471 (137)	475	35	1,379
Asthma Encounters at MEC Address	255	478 (138)	475	150	863

Table 6 provides counts of various combinations of energy efficiency improvements each home in the data received in the weatherization process. Note that in table 6 we combined those instances of door and window improvements where the source data indicated singular and plural nouns (window and windows, door, and doors). Among the Asthma encounters at MEC address a limited range of interventions were performed: air sealing, door(s), duct sealing, insulation, window(s). Although we did not include the particular weatherization interventions in our statistical analysis, our ability to estimate the impact in future analysis will be limited to four types. Our data includes only one asthma encounter at an address that received a door(s) intervention, a sample too small to yield any statistical power. Note the similarity in relative frequency of the interventions across data sets except for Window(s), Duct Sealing, and Window(s); Door(s) interventions.

Table 6: Weatherization Improvements by Dataset

Improvements	**MEC Address**	**Asthma Encounters at MEC Address**
AIR SEALING; INSULATION	2,270	101
AIR SEALING (only)	1,315	77
INSULATION (only)	1,179	37
AIR SEALING; INSULATION; WINDOW(s)	185	13
WINDOW(s) (only)	477	8
AIR SEALING; WINDOW(s)	92	7
AIR SEALING; INSULATION; DUCT SEALING	58	3
DUCT SEALING (only)	91	3
INSULATION; WINDOW(s)	56	3
AIR SEALING; DUCT SEALING	43	1
AIR SEALING; INSULATION; DOOR(s)	19	1
NA	24	1
AIR SEALING; DOOR(s)	20	0
AIR SEALING; INSULATION; WINDOW(s); DOOR(s)	18	0
AIR SEALING; WINDOW(s); DOOR(s)	12	0
DOOR(s) (only)	45	0
HEAT PUMP (only)	1	0
INSULATION; DOOR(s)	5	0
INSULATION; DUCT SEALING	5	0
INSULATION; WINDOW(s); DOOR(s)	11	0
WINDOW(s); DOOR(s)	103	0

The metric provided that measures the effectiveness of the energy efficiency improvement activities was the percent reduction in air leakage from air sealing. Table 7 describes the distribution of air sealing effectiveness among the MEC and asthma encounters at MEC data. After omitting negative and missing values, the asthma encounters at MEC address data were missing 39 observations and the MEC data were missing 1,204 observations. We know from an examination of the raw MEC data that percent reduction in leakage from air sealing was largely absent from the first year of the study period (2009) and complete for the later years (2011-2013). These later years corresponded to the years of the EWKC program. The percent reduction in leakage from air sealing was slightly higher among the Asthma Encounters at MEC addresses.

Table 7: Distribution of Air Sealing % Reduction by Dataset

	Observations	Mean (sd)	Median	Min	Max
MEC Address	4,925	22.16 (14.57)	22.23	0	93.28
Asthma Encounters at MEC Address	214	24.54 (13.01)	25	0	59.0

Demographics of Children with Asthma Encounters

To better understand the population in this study and to assess the potential introduction of bias into the analysis data we report the demographic distribution of the several datasets. Table 8 reports the racial composition of the asthma encounter data and the asthma encounters at MEC address data. The preponderant racial category across both datasets is Black/African American. Both the Black/African American, and White categories were over-represented while Hispanic and multi-racial were under-represented in the Asthma encounters at MEC address data. Neither of the racial categories American Indian or Alaskan Native, nor Pacific Islander were present in the Asthma encounter at MEC address data.

Table 8: Demographic Summary: Race

Race	All Asthma[1]	Asthma Encounters at MEC Address[1]
American Indian or Alaska Native	0.20%	NA
Asian	0.80%	0.90%
Black or African American	39.80%	42.30%
Hispanic	7.00%	4.70%
Multiracial	3.50%	2.20%
Native Hawaiian or Pacific Islander	0.20%	NA
White	27.20%	31.50%
NA[2]	21.20%	18.30%

[1] Percentage normalized to prevent double counting of patients
[2] Indicates unknown value: Declined/Refused, Other, Respondent Not Available, Unknown to Respondent, NA

The under-representiveness of Hispanic ethnicity among the asthma encounters at MEC address data is reported in Table 9. Demographics displayed by the ethnicity field (a separate field in the source data from Race what is reported in Table 8), one additional Hispanic encounter was identified among the asthma encounters at MEC address. The relative frequency of Hispanic ethnicity among the asthma encounters at MEC addresses was a little more than half that reported in the asthma dataset. The relative frequency of an unreported ethnicity was also higher among the asthma encounters at MEC address data.

Table 9: Demographic Summary: Ethnic Group

Ethnicity	**All Asthma**[1]	**Asthma Encounters at MEC Address**[1]
Hispanic/Latino	8.20%	5.00%
Non-Hispanic/Non-Latino	64.70%	71.90%
NA[2]	27.10%	23.00%

[1] Percentage normalized to prevent double counting of patients
[2] Indicates unknown value: Declined/Refused, Other, Respondent Not Available, Unknown to Respondent, NA

The reported male population among the asthma encounters at an MEC address was larger than what was reported for the underlying all asthma population (Table 10). Note however that sex was not available for over a quarter of both populations.

Table 10: Demographic Summary: Sex

Sex	**All Asthma**	**Asthma Encounters at MEC Address**
Female	30.0%	29.1%
Male	41.9%	45.7%
NA[2]	28.1%	25.2%

[1] Counts normalized by MRN to prevent double counting of patients

[2] Indicates unknown value: Declined/Refused, Other, NA

We also calculated the age distribution by data set. Unlike in the earlier demographic tables, here we report demographic details by asthma encounter rather than by the individual child. For the All-Asthma data the mean age of child at the time of encounter was 8 years, while the median age was slightly younger at 7.15 years (in decimal years). The sample population of the asthma encounters at MEC address age was slightly younger, with a mean age of 7.53 years and a median age of 6.61 years.

Children's Asthma Encounters

Not all asthma encounters provided by CMKC are of the same severity. Some encounters were associated with a routine checkup, while others were associated with the need for acute care intervention, for example, hospitalization. To reflect variation in asthma severity we categorize each asthma encounter according to a two-level ordinal scale.[7] The scale corresponds roughly to 1: controlled, 2: acute care visit. We generate this scale using both the ICD-9 diagnosis code and patient class as displayed in the medical record. Appendix C describes the generation of these ratings in more depth.

One method for understanding a child's asthma is to see how frequently they have any asthma encounter. When we look at the averages by data set it is clear that residing in a home that received weatherization attention was associated with fewer total asthma encounters per patient (Table 11). The All-Asthma averages provide a baseline with which to understand the figures associated with the Asthma Encounters at MEC addresses. The average number of asthma encounters per patient per year after weatherization was lower (1.67) than those patients at MEC addresses before weatherization (1.91) and the underlying population of children with asthma (1.89). The similarity of the mean number of encounters per child per year in Table 11 supports the assumption of similarity between the before weatherization observations at an MEC address and the underlying population of all children with asthma.

Table 11: Average Number of Asthma Encounters per Patient by Dataset

	Total Patients	**Mean Encounters per Patient per Year**
All Asthma Encounters	20,135	1.89
Asthma Encounters at MEC Addresses		

[7] Kane, "Revealing the Racial and Spatial Disparity in Pediatric Asthma."

Before Weatherization	207	1.91
After Weatherization	152	1.67

Table 12 extends these findings displaying the average number of encounters per child per year by year. The finding of Table 11 was reflected in those years with a sufficiently large sample size (2011-2013). The mean number of encounters per child for the All-Asthma population was stable across the period of study. The Before Weatherization and After Weatherization averages diverge substantially for those years in which we have an adequate sample size. As expected, the majority of the After Weatherization encounters occur later in the study period.

Table 12 Average Yearly Asthma Encounters per Child by Year and Data Set

All Asthma			Asthma at MEC Address Before Weatherization		Asthma at MEC Address After Weatherization	
Year	**Children**	**Mean Encounters per Child per Year**	**Children**	**Mean Encounters per Child per Year**	**Children**	**Mean Encounters per Child per Year**
2009	7,019	1.91	84	1.85	1	2
2010	6,799	1.86	74	1.97	13	2
2011	6,828	1.87	66	2.08	23	1.61
2012	7,474	1.91	48	1.94	51	1.67
2013	7,692	1.89	15	1.2	103	1.63

We observe in Table 13 substantial similarity between the asthma encounters at the MEC Addresses before weatherization events and the underlying All Asthma population. The Asthma Encounters at the MEC Addresses after weatherization have a lower percentage of the most serious asthma encounters compared with the before weatherization encounters and a higher percentage of the least severe encounters.

Table 11: Distribution of Asthma Encounter Levels by Dataset

	Encounter Level 1 Count (%)	**Encounter Level 2 Count (%)**
All Asthma Encounters	32,337 (47.8)	35,361 (52.2)
Asthma Encounters at MEC Addresses		

Before Weatherization	248 (45.2)	301 (54.8)
After Weatherization	164 (51.6)	154 (48.4)

We were able to group the asthma encounters by payment type listed in the medical record. This listing tells us how the asthma acute care visit was paid for. The table in Appendix D describes the basis for these ratings. Table 14 shows that there was relatively more commercial insurance among the Asthma Encounters at the MEC Addresses than there is in the population of All Asthma Encounters.

Table 12: Distribution of Payment type

Payment Type	**All Asthma Encounters**	**Asthma Encounters at MEC Address**
Medicaid or Government Program	50.1%	44.1%
Commercial insurance	24.9%	30.0%
Self-pay	6.2%	6.3%
Unknown	18.8%	19.6

Statistical Analysis

To estimate the impact of weatherization on pediatric asthma encounters we used a Poisson regression model. These models are typically used to express the probability of events occurring over time. We estimated the change in the frequency of such encounters that follows the child's home receiving energy efficiency upgrades. The outcome variable we focused on was the count of the most severe asthma encounters (level 2, see Appendix C) associated with an individual child over their time at risk. We calculated time at risk for the control population from the patient's first asthma encounter until the end of the study period or their home received weatherization; for the treatment population we calculated time at risk from weatherization until the end of the study period. The technical statistical term for this estimate is an Incidence Rate Ratio (IRR)[8]. The IRR measures medical encounters and should not be confused with asthma incidence, which is an epidemiological term that refers to the occurrence of new cases of the disease[9]. To minimize confusion, we use the abbreviation IRR. We calculated a 95% confidence

[8] Williams, "Models for Count Outcomes."
[9] "Principles of Epidemiology | Lesson 3 - Section 2."

interval (CI) around the IRR. Our model accounts for the temporal variation illustrated in Table 12, it incorporates observations for 17,550 patients under the age of 17.

We ran several models iteratively adding a new variable. Table 15 reports the results of the first two models. In model 1 we used one explanatory variable, whether the child was residing in a weatherized home for the period we were tallying their most serious asthma encounters. Model 2 adds a variable ("Kansas City") indicating if the home address was located in Kansas City, Missouri. We added the Kansas City variable to account for possible systematic differences between homes in Kansas City, Missouri, and those in the surrounding area.

Table 13: Associations between Weatherization and Severe Asthma Encounters (1)

	Model 1		**Model 2**	
	IRR	**95% CI**	**IRR**	**95% CI**
Weatherization	.66	.53 - .82	.66	.53 - .83
Kansas City			1.05	1.01 – 1.09

Models 1 & 2: Observations = 17,002. IRR: Incident Rate Ratio. CI: Confidence Interval

Focusing on the estimated effect of weatherization, in model 1, the IRR associated with weatherization is .66. This means that there were 34% fewer acute care visits for a child in a weatherized home (other things held constant) per year than those who lived in un-weatherized homes. We constructed a 95% confidence interval around this estimate and observed that in model 1 the confidence interval is under 1. In this model an IRR estimate of 1.00 implies no statistical difference in acute care visits following weatherization. A confidence interval that contains the value 1.00 also implies no statistical difference. The estimate of our most parsimonious model indicates that weatherization activity is strongly associated with a significant fall in the rate of pediatric asthma acute care visits.

Model 2 begins the addition of explanatory variables with a dichotomous variable indicating if the patient's address was located in Kansas City, MO. With the addition of this variable there was no change in the IRR estimated for weatherization (.66) and a very small change in the confidence interval. Our models indicates that children who live at Kansas City home address experienced the most severe kinds of asthma encounters 5% more frequently (other things held constant) than those who do not live in Kansas City.

Table 16 reports additional models. Model 3 adds a variable derived from the 2010 Decennial US Census to account for variation in the age of housing. The Post-1980 Home variable indicates if the mean year of construction by census block group was built after 1980. It is an imperfect variable in the sense that it is attributing a block group level measure to the parcel level. This variable is intended to account for potential systematic variation in housing by age of construction. Model 4 adds payment type dichotomous variables (as illustrated in Table 14 and Appendix D). These variables are a proxy to account for behavioral differences associated with payment type (e.g., Families with private insurance may utilize more medical resources).

Table 14: Associations between Weatherization and Severe Asthma Encounters (2)

	Model 3		**Model 4**	
	IRR	**95% CI**	**IRR**	**95% CI**
Weatherization	.67	.54 – .84	.67	.54 – .84
Kansas City	1.04	.99 – 1.08	1.03	.98 – 1.07
Post-1980 Home	.92	.87 - .97	.95	.91 – 1.00
Payment Type:				
Medicaid or Government Insurance			1.52	1.38 – 1.68
Commercial Insurance			1.32	1.19 – 1.47
Self-Pay			1.79	1.59 – 2.02

Models 3&4: n = 15,367. IRR: Incident Rate Ratio. CI: Confidence Interval

Critically for this report, the addition of the Post-1980 Home and Payment Type variables had minimal effect on the IRR estimated for weatherization. In both models the energy efficiency enhancements were estimated to reduce the incidence of acute care asthma visits by 33%. The stability of the IRR estimate for Weatherization supports our conclusion that EWKC had a strong effect on reducing pediatric acute care asthma encounters.

Model 3 indicates that accounting for the age of housing (Post-1980 Home) attenuates the significance of residing in Kansas City. Model 3 estimates the impact of living in a newer home as approximately 8% fewer acute care asthma visits per year. The Post-1980 Home IRR was itself attenuated by addition of the payment type variables. Of the additional variables estimated in model 4, commercial insurance is associated with a lower rate of acute care encounters. The reason for this relationship is not intuitively clear.

Conclusion

Based on our statistical examination, we report that the EWKC program of energy efficiency improvements reduced the frequency of acute care asthma encounters by 33% among those children aged 16 years and under who resided in a home that was weatherized. This is a substantial figure that should be scrutinized through the academic peer-review process and publicized among the stakeholders of the EWKC project and the general public. Our quantification of benefits from weatherization has immediate relevance to discussions around preparations for the impact of climate change and the mitigation of chronic pediatric illness. Our work suggests that the reduction in the number of acute care asthma visits be added to the benefits from weatherization activities. Our work also supports weatherization as a type of preventive medicine. High quality housing is a form of public health provision.

An important question which follows from our research is how generalizable are these results? Our analysis includes a sufficiently large number of observations to avoid the problems associated with small sample sizes. Other analyses are needed to confirm our findings, but we believe our findings will be robust for patients in single-family owner-occupied homes. Our study of EWKC does not shed light on the benefits from energy efficiency improvements to renters and the occupants of multi-family homes. We suspect the benefit profile will be similar for those groups, but the data provided by MEC contains scant information about those groups in particular. We suggest the development of a program like EWKC focused on rental properties and multi-family housing with a concordant study of the type we report in these pages.

This report functions as a hypothesis generating exorcise. The reported results should be interpreted as preliminary until they pass through peer review. Further analyses of these data are warranted. A look at just the asthma encounters matched to an address receiving energy efficiency upgrades is warranted. Such an analysis could incorporate housing type, the amount spent on each weatherization, relative effects of various energy efficiency-related interventions, and the amount of indoor air flow control.

It would be very useful to extend this analysis to estimate monetary benefits from a reduction in acute care asthma visits using the actual costs from CMKC. In such a quantification of benefits it is also important to include indirect benefits associated with estimates for lost time from work for parents and school absences.

Appendix A: Complete list of Cities included in analysis.

Table 15: Encounters per City: Three Principal Datasets (Complete)

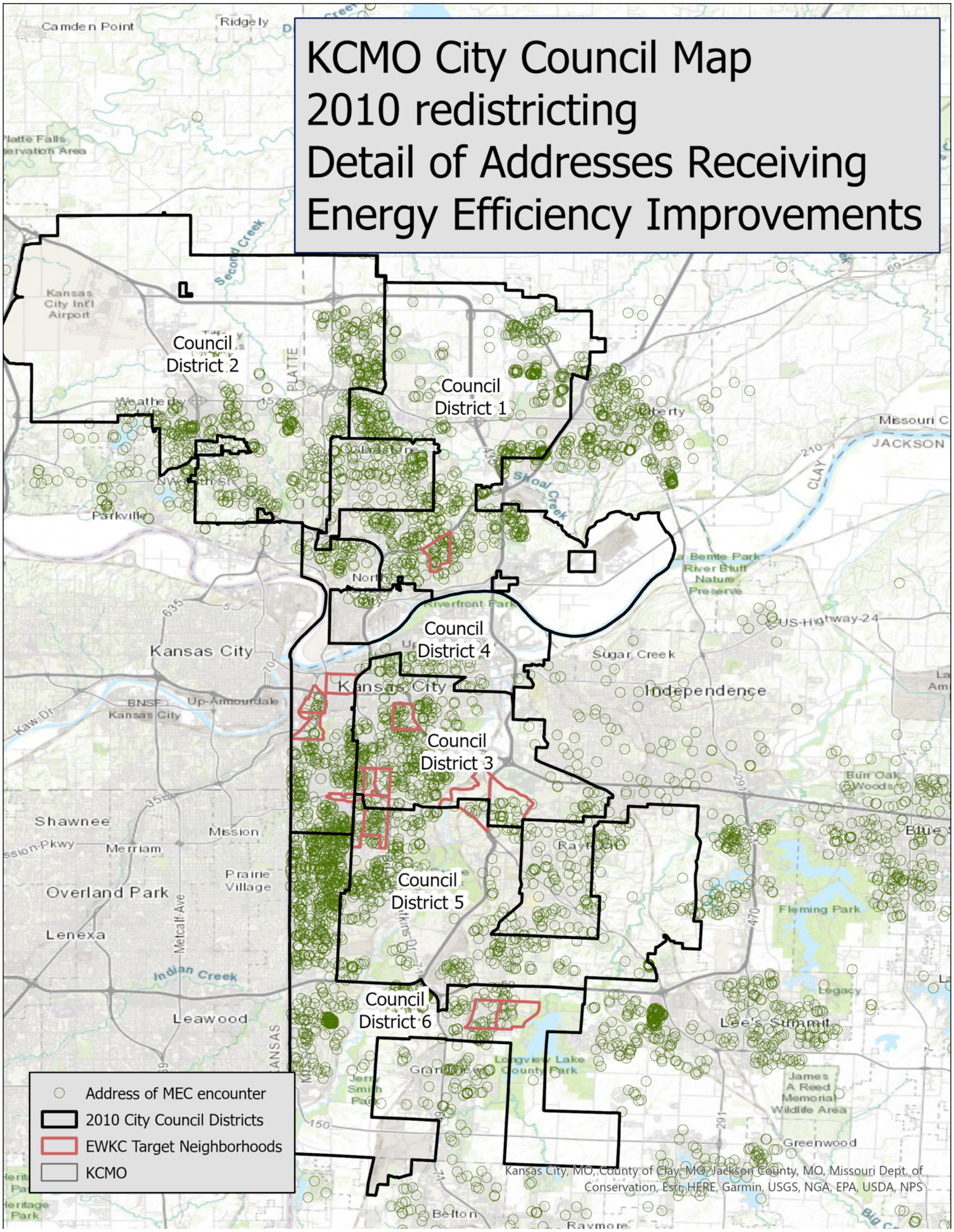
City	Asthma Encounters at MEC Address	MEC Address	Asthma Encounters[1]
KANSAS CITY	257	3,862	12,269
LIBERTY	14	396	455
LEES SUMMIT	12	525	1,109
UNKNOWN	10	651	243
RAYTOWN	7	96	866
BLUE SPRINGS	4	175	768
INDEPENDENCE	3	80	1,962
SMITHVILLE	3	26	150
GRAIN VALLEY	2	11	223
NORTH KANSAS CITY	2	16	101
GRANDVIEW	1	70	726
LAKE TAPAWINGO	1	0	12
RANDOLPH	1	0	25
AVONDALE	0	0	5
BELTON	0	34	3
BIRMINGHAM	0	0	1
BLUE RIDGE	0	0	1
BUCKNER	0	0	65
CLAYCOMO	0	0	8
EXCELSIOR SPRINGS	0	0	171
GLADSTONE	0	0	355
GREENWOOD	0	0	74
HOLT	0	0	33
HOMESTEAD VILLAGE	0	0	1
KEARNEY	0	5	148
LAKE LOTAWANA	0	3	4
LAKE WINNEBAGO	0	0	7
MARTIN CITY	0	0	7
MISSOURI CITY	0	0	2
MOSBY	0	0	1
OAK GROVE	0	5	116
OAKVIEW	0	0	15
OVERLAND PARK	0	0	1
PARADISE	0	0	1

City	Asthma at MEC Address	MEC Address	Asthma Encounters[1]
PARKVILLE	0	24	1
PECULIAR	0	3	0
PLATTE CITY	0	0	1
PLEASANT VALLEY	0	0	42
RAYMORE	0	41	0
RIVERSIDE	0	6	0
ROCHESTER	0	0	1
SIBLEY	0	0	12
SUGAR CREEK	0	0	121
UNITY VILLAGE	0	0	27
WOOD HEIGHTS	0	0	2

1 Counts normalized by Medical Record Number to prevent double counting of patients

Appendix B: Map of KCMO 2011 – 2020 City Council Districts

Figure 2: Map of KCMO City Council Districts and MEC Addresses (detail)



Appendix C: Determining Asthma Severity Level

Each asthma encounter is assigned a severity level based on ICD9 code (Table 18) and another severity level based on patient class (Table 19). If there is a disagreement between these two severity levels the highest of the two is used.

Table 16: Severity Level because of Diagnosis Code

Diagnosis Code	**Diagnosis Name**
Severity Level 1	
493	EXTRINSIC ASTHMA, NOS
493.1	INTRINSIC ASTHMA, NOS
493.2	CHRONIC OBSTRUCTIVE ASTHMA, NOS
493.82	COUGH VARIANT ASTHMA
493.9	ASTHMA, UNSPECIFIED
Severity Level 2	
493.02	EXTRINSIC ASTHMA, W (ACUTE) EXACERBATION
493.12	INTRINSIC ASTHMA, W (ACUTE) EXACERBATION
493.22	CHRONIC OBSTRUCTIVE ASTHMA, W (ACUTE) EXACERBATION
493.81	EXERCISE INDUCED BRONCHOSPASM
493.92	ASTHMA, UNSPECIFIED, W (ACUTE) EXACERBATION
493.01	EXT ASTHMA W STATUS ASTH
493.11	INT ASTHMA W STATUS ASTH
493.21	ASTHMA, CHRONIC OBSTRUCTIVE W ASTHMATICUS
493.91	ASTHMA W STATUS ASTHMAT

Table 17: Asthma Severity because of Patient Class

Severity Level 1	
	CLIENT REFERRED
	OUTPATIENT
	DIAGNOSTIC/TREATMENT REFERRED
Severity Level 2	
	EMERGENCY
	SAME DAY CLINIC
	INPATIENT CHAMPUS
	INPATIENTS
	INPATIENTS WITH KS MEDICAID
	OBSERVATION CHAMPUS
	OBSERVATION KS MEDICAID
	OBSERVATION PATIENTS

Appendix D: Determining Payment Type

Table 18: Classification of Payment Type

Group 1: Government Insurance	
	MCD MO BLUE ADVANTAGE PLUS
	MCD MO FIRST GUARD
	MCD KS MANAGED CARE
	MCD KS FEE FOR SVC
	MCD MO MANAGED CARE
	OTH GVT PROGRAMS
	MCD MO FAMILY HEALTH PARTNERS
	MCD KS FAMILY HEALTH PARTNERS
	MCD MO FEE FOR SERVICE
Group 2: Private Insurance	
	COMMERCIAL INS MANAGED CARE
	BLUE CROSS MANAGED CARE
	BLUE CROSS INDEMNITY
	CHAMPUS
	COMMERCIAL INS INDEMNITY
Group 3	
	SELF PAY
Group 4	
	UNKNOWN

Appendix E: Bibliography

"American Housing Survey (AHS) - AHS Table Creator." Accessed June 12, 2020. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=28140&s_year=2015&s_tablename=TABLE1&s_bygroup1=4&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1.

Centers for Disease Control and Prevention. Control Asthma | 6|18 Initiative | CDC, March 10, 2022. https://www.cdc.gov/sixeighteen/asthma/index.htm.

Craig, Peter, Srinivasa Vittal Katikireddi, Alastair Leyland, and Frank Popham. "Natural Experiments: An Overview of Methods, Approaches, and Contributions to Public Health Intervention Research." *Annual Review of Public Health* 38, no. 1 (March 20, 2017): 39–56. https://doi.org/10.1146/annurev-publhealth-031816-044327.

De Vocht, Frank, Srinivasa Vittal Katikireddi, Cheryl McQuire, Kate Tilling, Matthew Hickman, and Peter Craig. "Conceptualising Natural and Quasi Experiments in Public Health." *BMC Medical Research Methodology* 21, no. 1 (December 2021): 32. https://doi.org/10.1186/s12874-021-01224-x.

Jerrett, Michael, Richard T. Burnett, C. Arden Pope, Kazuhiko Ito, George Thurston, Daniel Krewski, Yuanli Shi, Eugenia Calle, and Michael Thun. "Long-Term Ozone Exposure and Mortality." *New England Journal of Medicine* 360, no. 11 (March 12, 2009): 1085–95. https://doi.org/10.1056/NEJMoa0803894.

Johnson, Linda, Christina Ciaccio, Charles S. Barnes, Kevin Kennedy, Erika Forrest, Luke C. Gard, Freddy Pacheco, Paul Dowling, and Jay M. Portnoy. "Low-Cost Interventions Improve Indoor Air Quality and Children's Health." *Allergy and Asthma Proceedings* 30, no. 4 (July 1, 2009): 377–85. https://doi.org/10.2500/aap.2009.30.3257.

Kane, Natalie. "Revealing the Racial and Spatial Disparity in Pediatric Asthma: A Kansas City Case Study." *Social Science & Medicine* 292 (January 2022): 114543. https://doi.org/10.1016/j.socscimed.2021.114543.

Pope, C. Arden, and Douglas W. Dockery. "Health Effects of Fine Particulate Air Pollution: Lines That Connect." *Journal of the Air & Waste Management Association* 56, no. 6 (June 2006): 709–42. https://doi.org/10.1080/10473289.2006.10464485.

"Principles of Epidemiology | Lesson 3 - Section 2," May 18, 2012. https://www.cdc.gov/csels/dsepd/ss1978/lesson3/section2.html.

Tonn, Bruce, Erin Rose, and Michaela Marincic. "Cascading Benefits of Low-Income Weatherization upon Health and Household Well-Being." *Building and Environment* 242 (August 2023): 110470. https://doi.org/10.1016/j.buildenv.2023.110470.

Williams, Richard. "Models for Count Outcomes," April 12, 2022. https://www3.nd.edu/~rwilliam/xsoc73994/CountModels.pdf.