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ECONOMIC AND ENVIRONMENTAL IMPACTS OF ENERGY EFFICIENCY INVESTMENT ON LOCAL MANUFACTURERS

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ABSTRACT

The main goal of this study is to estimate the community-wide economic and environmental impacts of energy efficiency investment on the local manufacturing using data with different granularity. A systematic framework is developed by using multiple scale/layer of data. Result shows that a $14M investment in HVAC upgrade to reduce energy and cost in the economy of the Montgomery County, Ohio can result in a total local economic impact of $22M, stemming from the $14.5M coming from direct impact, $2.8M coming from indirect impact, and $4.7M coming from induced impacts. Job creation over the investment period yields a total of 106 jobs. Analysis provides insight into the most important types of economic effects to the local industries. From an environmental perspective, short term economy-wide carbon dioxide emissions increase because of the increased community-wide economic activities spurred by the production from local manufacturers and installation of energy efficiency measures, however the resulting energy savings provide continuous carbon dioxide reduction for various target savings.

INTRODUCTION

The American Council of Energy Efficient Economy (ACEEE) reports that the cost to reduce energy is on average 2.5 cents per kilowatt hour, 73% less than the second least expensive resource, natural gas [1]. In the U.S. currently 29 states have some form of renewable or energy efficiency standards [3]. Household decisions that directly affect energy consumption (e.g. choices about appliance purchase and use or home heating and cooling) account for more than 30 percent of U.S. CO_2 emissions, and a comparable amount of overall energy use [7]. However, U.S. residential and commercial energy use increased by respectively 18.4% and 22.9% from 2001 – 2011 [8]. The population increase was only 9.5%. According to the Intergovernmental Panel on Climate Change Fifth Assessment Report, “Warming of the climate system is unequivocal,” and “Human influence on the climate system is clear. [12]”

Then what is the solution if any? It is critical to make carbon reduction / sustainability important to people. A special advisor to Mayor Bloomberg in his role as C40 (a global network of cities committed to climate change initiatives) chair, stresses that, "At the end of the day, waste, water, energy consumption and buildings and transportation policy -- those are the jobs of mayors in cities [2]. Many cities committed to sustainability and have adopted goals relative to a variety of sustainability indicators. The city of Cincinnati, Ohio adopted a green energy opt out for all residents in August 2013 [6]. This initiative has provided a jump start toward achieving greenhouse gas emission reduction goals of 8% within four years, 40% within 20 years, and 84% by 2050. New York City set an ambitious goal to reduce citywide greenhouse gas

(GHG) emissions 30 percent by the year 2030. Beside this movement from large cities, there are movements in the domain of small cities and communities. In Ohio, three smaller communities have committed to 100% renewable energy and are close to achieving their goal (Oberlin, Hamilton, and Yellow Springs).

We believe that it is very important to link sustainability action plan to the community economic impact because even sustainability skeptics may be persuaded to see the sustainability value from it if there is positive economic impact in their community. In this end, the main question of this paper is as follow: "Can a more accurate assessment of the economic and environmental impact of energy efficiency adoption in community be measured if we know the spectrum of building energy effectiveness and cost effectiveness of energy reduction as well as the manufacturing base within a community?"

DATA

The geographical area of this study is Montgomery County located in the U.S. state of Ohio. According to the 2011 census data, it has a population of 534,325 [16]. The county seat is Dayton. It has a total area of 1,202.6 km^2, of which 1,195.4 km^2 (or 99.40%) is land and 7.2 km^2 (or 0.60%) is water. In the U.S., economic input-output data is available at national, state, regional, and local levels. There are about 445 aggregated sectors available in the U.S.[15]. Regional input-output data for Montgomery County, Ohio is used. Data output includes direct, indirect, and induced effects from production changes brought by increases in final demand. For example, the addition of HVAC upgrade to reduce heating and cooling energy in a community increases final demand for materials and supplies associated with HVAC equipment, impacting directly local manufacturing (if it exists) and local contractual services for installation. Indirect effects result from changes in the demand for the main goods and services necessary for production of a sector's output. Historical energy data are merged with county maintained building databases for all residential, commercial, governmental, and industrial buildings. This data includes use type (residential, office, etc.), square footage, and number of floors. Weather-normalization regression approaches based upon the PRISM approach [9] are used to disaggregate energy use into annual heating, cooling, lighting/appliances, and water heating energy use. With known square footage, the energy intensity in each category can be determined. Local benchmarks are established in each energy category for each building type. Each building can be compared to the appropriate benchmark. Rough energy models are established for each building and residence [11, 17]. The savings potential in all energy categories for each residence, along with the simple payback, can then be estimated. In order to capture the community-wide change in carbon dioxide emission, input-output based life cycle assessment (LCA) is adopted. Methodology developed from previous life cycle analysis studies have used to integrate the top-down LCA framework for assessing the economic and environmental implication [4, 5].

METHODOLOGY

The Leontief Input-Output model [13, 14] is the backbone of this model. It takes user specific inputs and generates economic impact output through matrices based on actual historical economic data. Input-output analysis captures inter-institutional transactions, which includes cash flows from business to households, people to government, and government to people. Induced effects result from expenditures made by employees of the directly and indirectly effected industries on general consumer goods and services in a geographical area. For example, households may spend their energy bill savings on entertainment industries or food service industries located in a geographical reason of the consideration. Input-output model generates key indicators including job creation, total production output, labor income, and total value added.

The major assumption employed for the traditional Leontief model is the fixed direct requirement matrix A, which represents the fraction of a dollar required by a sector to produce a dollar of output. In other words, input coefficients are dollar inputs from industry i needed to product $1 output from industry j with the given monetary transaction table. It is usually utilized to analyze the change of the total production vector (x) by a change of the final demand vector (y) as shown in Equation 1,

$$\mathbf{\Delta x} = (\mathbf{I} + \mathbf{A} + \mathbf{A}^{2} + \mathbf{A}^{3} + ...\mathbf{A}^{n})\mathbf{\Delta y} \qquad \text{(Eq. 1)}$$

where A is the n x n inter-industry direct requirement matrix, y is the monetary amount of the final demand column vector, x is the total monetary industry output column vector, and v is the monetary value added row vector. Even if a direct requirement matrix A is useful, it only considers direct input from other industries and ignores indirect input. For example, the automotive industry needs direct input from chemical product industry and direct input from other industries such as rubber industry, plastic industry, etc. These other industries also needs direct input from the chemical product industry which is the indirect input in terms of automotive industry level. A power series expansion as shown in Equation 1 take into account both the direct and indirect requirements for the final demand change. The sum of these round-by-round effects, including final demand, is total production output change. In this way, the input-output framework shows the total supply chain effects of producing goods and services in an economy. The magnitude of the direct, indirect, and total effects is completely dependent on the values of the A matrix. Thus it is possible for indirect effects to be larger than the direct effects. Social Accounting Matrix (SAM) is adopted to capture induced effects. Traditional input-output analysis only captures the inter-industrial transactions. Unlike traditional input-output analysis, SAM captures inter-institutional transactions, which includes cash flows from business to households, from people to government, and from government to people. Induced effects result from expenditures made by employees of the directly and indirectly effected industries on general consumer goods and services in a geographical area. Key indicators of the induced economic impacts includes such as job creation, labor income, and total value added. In this study, job (full and part-time employment for one year) and total production outputs (i.e. direct, indirect, and induced) are considered.

ANALYSIS

Table 1 lists the local economic sectors associated with HVAC upgrade/ HVAC equipment manufacturing in the Montgomery County, OH. Total economic activities (i.e. $ production) of the aggregated sectors such as “Air conditioning, refrigeration, and warm air heating equipment manufacturing”, “Automatic environmental control manufacturing”, and “Maintenance and repair service” sectors. In order to estimate economy-wide impacts for Montgomery County resulting from a specified investment amount in HVAC upgrade, the first step is to allocate the specified investment dollars to the appropriate manufacturing and service sectors.

Table 1. ECONOMIC SECTORS RELATED TO HVAC UPGRADE IN THE MONTGOMERY COUNTY, OH.

Local Economic Sectors associated with HVAC manufacturing/maintenance
Air conditioning, refrigeration, and warm air heating equipment manufacturing
Heating and air conditioning combination units manufacturing
Heating equipment, warm air (i.e., forced air), manufacturing
Steam pressure controls, residential and commercial heating-type, manufacturing
Sequencing controls for electric heating equipment manufacturing
Limit controls (e.g., air-conditioning, appliance, heating) manufacturing
Heating regulators manufacturing
Heating and cooling system controls, residential and commercial, manufacturing
Automatic environmental control manufacturing
Thermostats (e.g., air-conditioning, appliance, comfort heating, refrigeration) manufacturing
Steam pressure controls, residential and commercial heating-type, manufacturing
Sequencing controls for electric heating equipment manufacturing
Limit controls (e.g., air-conditioning, appliance, heating) manufacturing
Heating regulators manufacturing
Heating and cooling system controls, residential and commercial, manufacturing
Maintenance and repair construction of residential structures

Table 2 shows the round-by-round local community-wide economic impact after $14M investment are made to these sectors. Investment for each recipient sectors are allocated proportional to the total dollar amount of production output from each sector. A $14M investment in HVAC upgrade to reduce energy and cost in the economy of the Montgomery County can result in a total local economic impact of $22M, stemming from the $14.4M coming from direct impact, $2.8M coming from indirect impact, and $4.7M coming from induced impacts. Job creation over the investment period yields a total of 106 jobs, with 45, 21, and 40 coming respectively from direct, indirect, and induced impacts. It provides insight into the most important types of economic effects and the percentile contribution of those to the local industries.

Table 3 shows the change of total output of selected industry (out of 445) sectors after a $14M investment are made. Some sectors would experience greater direct impacts, while others would experience primary indirect and/or induced impacts.

Table 2. TOTAL ECONOMIC IMPACT OF HVAC UPGRADE INVESTMENT

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	44.7	$5,654,760	$7,061,415	$14,394,319
Indirect Effect	21.1	$1,149,939	$1,686,901	$2,837,318
Induced Effect	40.2	$1,704,422	$2,870,294	$4,707,781
Total Effect	106	$8,509,120	$11,618,610	$21,939,418

Table 3. LOCAL ECONOMIC IMPACT OF HVAC UPGRADE INVESTMENT IN MONTGOMERY, OHIO.

Description	Direct	Indirect	Induced	Total
Air conditioning, refrigeration, and warm air heating equipment manufacturing	$6,927,233	$2,711	$91	$6,930,036
Maintenance and repair construction of residential structures	$4,776,549	$77	$5,880	$4,782,507
Automatic environmental control manufacturing	$2,690,537	$1,120	$10	$2,691,666
Wholesale trade businesses	$0	$395,857	$196,870	$592,727
Management of companies and enterprises	$0	$306,523	$34,329	$340,851
Architectural, engineering, and related services	$0	$123,986	$11,130	$135,116
Telecommunications	$0	$114,263	$134,998	$249,261
Monetary authorities and depository credit intermediation activities	$0	$102,909	$153,102	$256,011
Securities, commodity contracts, investments, and related activities	$0	$102,841	$135,184	$238,024
Software publishers	$0	$81,810	$11,388	$93,198
Transport by truck	$0	$77,194	$36,705	$113,898
Maintenance and repair construction of nonresidential structures	$0	$75,205	$23,567	$98,772
Electric power generation, transmission, and distribution	$0	$70,307	$116,234	$186,541
Imputed rental activity for owner-occupied dwellings	$0	$0	$668,170	$668,170
Private hospitals	$0	$1	$409,688	$409,690
Offices of physicians, dentists, and other health practitioners	$0	$1	$325,073	$325,073
Food services and drinking places	$0	$45,147	$304,719	$349,866
Real estate establishments	$0	$67,587	$255,943	$323,530
Nursing and residential care facilities	$0	$0	$104,144	$104,144
Medical and diagnostic labs and outpatient and other ambulatory care services	$0	$28	$104,077	$104,105
Retail Stores - General merchandise	$0	$38,866	$84,277	$123,144
441 sectors more …..				

Figure 1 summarizes the combined economic effects for some of sectors out of 445 economic sectors listed in the input-output data. It maps the percentile contribution of direct, indirect, and induced effects of some sectors caused by the $14M community-wide investment in HVAC upgrades. For example, economic sectors such as 1) air conditioning, refrigeration, and warm air heating equipment manufacturing, 2) automatic environmental control manufacturing, and 3) maintenance and repair construction of residential structures have almost 99% of the direct economic effect. The following sectors are most strongly effected indirectly; wholesale trade, engineering services, telecommunications, truck transportation, electrical power generation, transmission, and distribution. Finally, the most important induced economic impacts are associated with economic sectors such as imputed rental activity for owner-occupied dwellings, private hospitals, health services, food services/drinking places, and insurance carriers. These sectors have no inter-industry transactions with the insulation related activities directly, but households may spend the increased income salaries for activities in these non-production related industries, thereby boosting the local economy. The indirect and induced effects for HVAC upgrades reflects the fact that local business rely on other local businesses and, combined, their wages stay local.

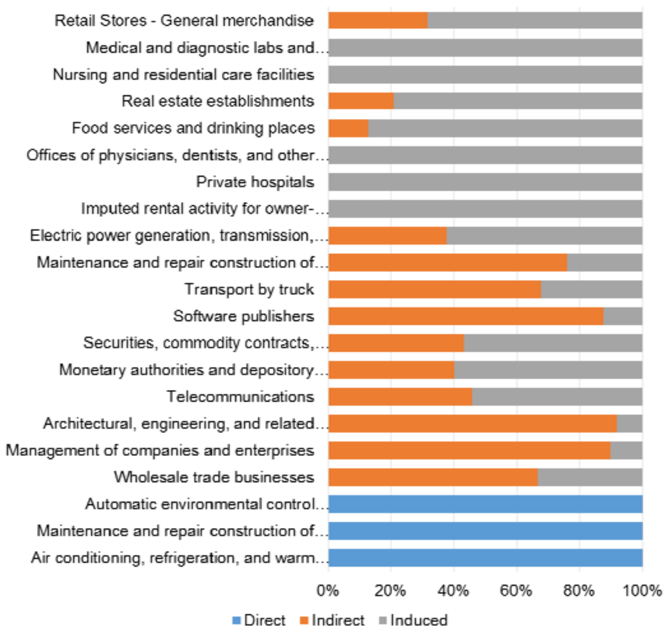

Figure 1. MAJOR ECONOMIC SECTORS AFFECTED BY THE INVESTMENT ON HVAC IN THE MONTGOMERY COUNTY, OH.

This analysis is based upon an assumed constant cost of investment relative to savings. The investment cost and economic impact are linear with savings. If a community wanted to get greater savings penetration, they would need only to scale their investment. The reality is that deeper penetration will inevitably require a greater than linear investment. The reason is that increased investment generally will capture more efficient residences where efficiency upgrades will not realize as much savings. A more cost effective strategy for investment in energy reduction in a community could be realized if investments were allocated to support actions in the worst residences first. In other words, the most cost effective community energy savings would be derived if the measures having the lowest levelized cost from among all possible measures within the whole community were implemented first; the next best second; and so on. Out of all possible measures, natural gas heating energy use in a nearby town Montgomery County, with just over 2,000 residences is considered. Assumed is that the housing stock considered in the nearby town mirrors that of Montgomery County, so that the investment costs per savings estimated in the nearby community reflect that of Montgomery County. This assumption is reasonable as the age of the housing stock and affluence in the communities are nearly the same. For this town, energy models were developed for all residences based upon historical energy use and available residential building information. From these energy models, savings from and investment costs required to implement heating energy reduction measure are estimable for each residence.

Figure 2 shows a plot of investment cost per MBTU saved annually for the hierarchy of residences (from worst to best) in this town from furnace upgrade generated from previous study [17]. Dotted line shows the levelized average cost of furnace upgrade shown in McKinsey's 2009 study [10] for a furnace upgrade. As is apparent in the graphs, the collective levelized cost per one million British thermal unit for each measure is "biased" by the lowest individual house levelized cost per one million.

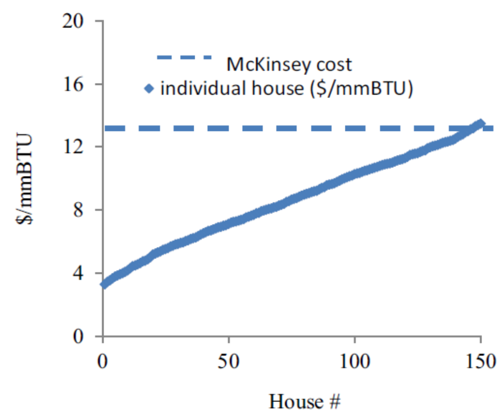

Figure 2. LEVELIZED COST FOR FURNACE UPGRADE FOR INDIVIDUAL HOUSES PRESENTED IN ASCENDING ORDER OF COST EFFECTIVENESS [17]

Figure 3 is a plot of investment cost per MBTU saved annually for furnace upgrades versus collectively community-wide HVAC savings. Clear from these figures is that the investment cost to achieve unitary savings ($/MBTU) increases through the hierarchy of energy effectiveness in residences, moving from the worst to first houses although the investment per residence remains roughly constant. Additionally, it is clear that an increasing cost per savings is required to gain greater savings penetration in the community. These results help to improve the estimate of a local economic impact of an energy reduction projects from specific measures for Montgomery County, Ohio. Table 4 shows the level of target energy savings and the associated investment required to achieve annual saving for 15 years during the project years. It presents the percentage heating energy reduction community-wide versus annual energy cost savings, investment for HVAC upgrade considered. This table shows that lower savings for the community can be realized from investment. Deeper savings are possible, though, but with less attractive economic benefit to the investors. However, the economic benefit derived from savings does not begin to measure the complete economic impact to the community.

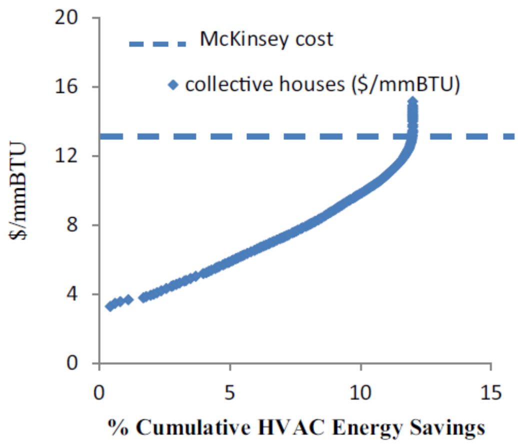

Figure 3. LEVELIZED COST FOR FURNACE UPGRADE FOR THE COLLECTIVE GROUPING OF HOUSES PRESUMING THAT HOUSES ARE IMPROVED IN ORDER OF LEVELIZED COST AS A FUNCTION OF CUMULATIVE HVAC ENERGY SAVINGS [17]

Table 4. LEVEL OF INVESTMENT FOR HVAC UPGRADE

	HVAC Upgrade	
Savings (%)	Ann. Savings ($)	Investment ($)
1	91,879	612,524
2	183,757	1,408,806
3	275,636	2,388,844
4	367,515	3,552,640
5	459,393	4,900,193
6	551,272	6,431,504
7	643,150	8,146,572
8	735,029	10,045,397
9	826,908	12,127,979
10	918,786	14,394,318
11	1,010,665	16,844,415

RESULTS

There are two parts of economic impacts considered in this paper. First part is the short term immediate economic impacts to the community which is accrued by the investment on the local manufacturing sectors and the engineering service sectors related to HVAC upgrade. It includes direct, indirect, and induced community impacts such as the increase in the production of local manufacturing, increase in local goods and service, and the number of job created in the community. Direct effects represent production changes brought by increases in final demand. For example, the HVAC upgrade to reduce heating and cooling energy, increases final demand for materials and supplies. Indirect effects result from changes in the demand for the main goods and services necessary for production of a sector's output.

Figure 4 shows the community-wide economic impact for various level of the HVAC energy reduction target through the investment of the HVAC upgrades. It shows the combined incremental change of the short term total economic impacts. For example, achieving a 10% target saving with a $14M investment on HVAC upgrade results in a $23.5M economy wide economic effect, with 61, 12, and 20 percent of this impact coming from direct, indirect, and induced effects. About 7 percent of the total economic impacts accrued from the second part of the economic impacts considered. These second part economic impacts accrued from the direct dollar saving from the energy reduction and the associated induced community economic activities for the beginning year of the project. For example, households may spend their energy bill savings on entertainment industries or food service industries located in a geographical reason of the consideration. Investment in HVAC upgrades generate greater initial economic-wide impact compare to other energy saving measures such as attic insulation, window upgrade, etc. because it requires a greater amount of initial investment for the worst systems in order to effect equivalent savings percentage in the community. Overall, a deeper saving target yields an increasingly greater short term economic impact in the community, as the investment required to achieve additional savings increases non-linearly.

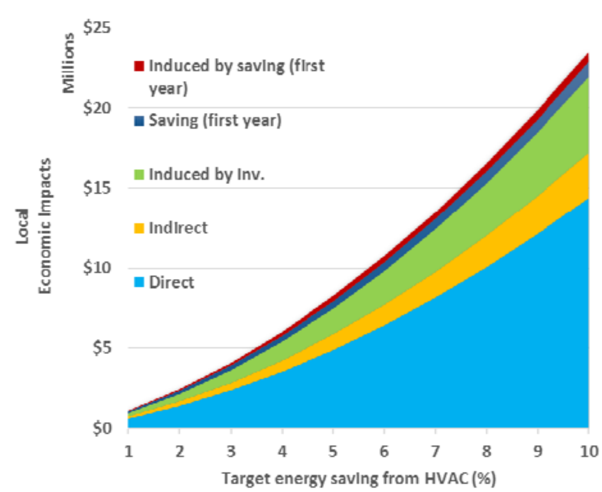

Figure 4. SHORT TERM ECONOMIC IMPACTS OF INVESTMENT ON HVAC SYSTEM IN MONTGOMERY COUNTY, OH.

Figure 5 shows the accumulative long term economic impacts of the community which considers the direct energy dollars saved through the implementation of the HVAC upgrade in the households and the associated community-wide savings induced impacts for 15 years life-time (i.e. top portion of the graph). Direct, indirect, and induced impacts from the investment doesn't change, however savings impact through 15 years evidently shows the much greater economic impact to the community. Energy escalation rate 3.3% is considered for calculating the savings impact for each target energy saving percentage.

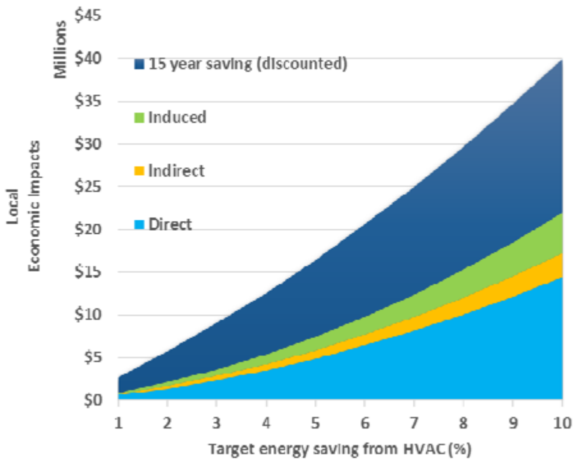

Figure 5. LONG TERM ECONOMIC IMPACTS BY INVESTMENT ON HVAC SYSTEM IN MONTGOMERY COUNTY FOR SPECIPIC TARGET SAVINGS.

Figure 6 shows the amount of the annual community-wide carbon dioxide for achieving 10% energy reduction from HVAC system upgrade.

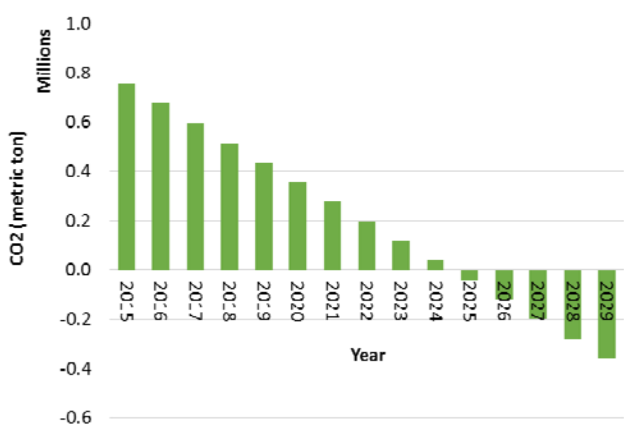

Figure 6. AMOUNT OF THE COMMUNITY-WIDE CARBON DIOXIDE EMISSSION FROM LOCAL ECONOMIC SECTORS AFTER $14M HVAC INVESTMENT.

In the base year (i.e. 2015), the total community residential energy consumption in the area is estimated to 1.5 x 10^7 MBTU. Therefore the estimated carbon dioxide (CO_2) emission generated from the residential housings in the community is 7.56 x 10^5 metric tons in, assuming that a natural gas carbon intensity of 117 lb CO2/MBTU. This community-wide CO_2 generation contains the amount of emission accrued from direct, indirect, and induced economic activities. Although, CO_2 emissions increase from the investment in the project initiation, energy savings from the HVAC upgrade will provide continuous reduction of the CO_2 emission to the community over the life of the investment. Considering the 10% target residential energy savings and no efficiency degradation from the HVAC upgrades, community heating emissions will be reduced by 7.96 x 10^4 metric tons every year. Therefore, carbon dioxide payback time (i.e. amount of additional carbon dioxide added to the community because of the investment / annual carbon dioxide reduction from saving) is estimated to be about 10 years (i.e. break-even point). After 10 years forward, this project will actually provide negative carbon dioxide emission (i.e. net savings).

CONCLUSIONS

We believe that sustainability advance in the U.S. is a local phenomenon. Real progress is being achieved by cities/towns/communities throughout the nation. Progress, however, is generally not homogeneous, with many more communities not acting compared to the number taking the initiative to do so. For those communities taking action, the local visioning and goal setting is often ad hoc or simply a carbon copy of goals established by leading cities.

The local economic and environmental impacts from achieving sustainability targets will be different for each community, depending upon the assets (manufacturing, services, land, etc…) that each community has. Integrative, interdisciplinary research is necessary to develop local customization by linking local economic analysis, local environmental impact analysis, and highly granular community based energy consumption data. On that end, we tried to demonstrate that more granular data (i.e., historical energy use for all buildings) can be utilized to improve the accuracy of local economic impact estimates for achieving sustainability goals and subsequent optimization of goals for a community.

The aim of this study is to show the comprehensive insights and connection among achieving energy target reductions for a community energy use, economic and environmental impacts through specific energy efficiency measure. Our ultimate goal is to develop an impact resource to cities/towns/communities throughout the country which enables local optimization of sustainability goals and improved opportunities for cities/towns/communities to communicate the value of sustainability to their communities.

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