Energy xxx (2014) 1–10

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Economic and environmental impacts of community-based residential building energy efficiency investment

Jun-Ki Choi [a, b, *], Drew Morrison [a], Kevin P. Hallinan [a, b], Robert J. Brecha [a, c]

[a] Renewable and Clean Energy, University of Dayton, Dayton, OH 45469-0238, USA
[b] Mechanical and Aerospace Engineering, University of Dayton, Dayton, OH 45469, USA
[c] Physics, University of Dayton, Dayton, OH 45469, USA

ARTICLE INFO

Article history:
Received 24 July 2014
Received in revised form
28 September 2014
Accepted 26 October 2014
Available online xxx

Keywords:
Community based energy efficiency
Input–output analysis
Local economic impacts
Worst-first energy efficient measure
Life cycle assessment

ABSTRACT

A systematic framework for evaluating the local economic and environmental impacts of investment in building energy efficiency is developed. Historical residential building energy data, community-wide economic input–output data, and emission intensity data are utilized. The aim of this study is to show the comprehensive insights and connection among achieving variable target reductions for a residential building energy use, economic and environmental impacts. Central to this approach for the building energy reduction goal is the creation of individual energy models for each building based upon historical energy data and available building data. From these models, savings estimates and cost implications can be estimated for various conservation measures. A ‘worst to first’ (WF) energy efficient investment strategy is adopted to optimize the level of various direct, indirect, and induced economic impacts on the local community. This evaluation helps to illumine opportunities to establish specific energy reduction targets having greatest economic impact in the community. From an environmental perspective, short term economy-wide CO_2 emissions increase because of the increased community-wide economic activities spurred by the production and installation of energy efficiency measures, however the resulting energy savings provide continuous CO_2 reduction for various target savings.

1. Introduction

Cities are responsible for anywhere from 50 to 75% of climate change, where the lower bound assigns climate impact to the producers and the upper bound is assigned to consumer of climate impact contributions [1,2]. It is clear that research which has the potential to diminish this impact is vital. What is also clear, especially in the U.S., is that federal-level policy has not emerged to reduce this impact [3]. Yet despite the dearth of large-scale policies, numerous cities throughout the U.S. and internationally have committed to sustainability. In 2005 more than 1000 U.S. mayors signed a pledge to meet the goals stated in the Kyoto protocol and to lobby their states and the federal government to act on climate protection.

Studies [4,5] found that cities that are more fiscally strapped are more likely to commit to sustainability, especially if they are mayor-led cities. The research presented in this paper is established in this context. For those cities and towns showing commitment to sustainability, many have adopted goals relative to a variety of sustainability indicators. For example, the City of Portland's Climate Action Plan has put Portland on a path to achieve a 40 percent reduction in carbon emissions by 2030, and an 80 percent reduction by 2050 [6,7]. In August 2013, the city of Cincinnati adopted a green energy opt out for all residents [8]. 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. Boulder Colorado's 2012 plan calls for carbon neutrality by 2020 [9]. With its PlaNYC, New York City set an ambitious goal to reduce citywide greenhouse gas (GHG) emissions 30 percent by the year 2030 [10]. We could go on and on. But, the exciting thing is that this is not just the domain of large cities. In Ohio alone, three smaller communities have committed to 100% renewable energy and are close to achieving their goal (Oberlin, Hamilton, and Yellow Springs).

While the fervor for goal setting is strong, the reality is that many of those cities and towns committing to goals do not have an etched path to get there and don't understand the economic implications of their goals. Moreover, there remain many more cities, towns, and counties which aren't acting. There is a strong need to motivate new

* Corresponding author. Renewable and Clean Energy, University of Dayton, 300 College Park Ave., Dayton, OH 45469-0238, USA. Tel.: +1 937 229 5344; fax: +1 937 229 4766.
E-mail address: jchoi1@udayton.edu (J.-K. Choi).

http://dx.doi.org/10.1016/j.energy.2014.10.082
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communities to begin a path toward sustainability. It is imperative that communities be provided resources to help sell sustainability to their local constituents. Linking sustainability to community-wide economic impact is essential, because even sustainability skeptics may be persuaded to see value from it if there is positive economic impact in their community. Further it is essential that communities understand the value of achievement relative to the various sustainability goals so that priorities can be established. Communities should first investigate how sustainability might be conceptualized for their community and how this understanding could lead to distinct programmatic priorities [11–13]. Particularly important for communities which are just now considering sustainability is an understanding of the economic impact locally [14–16]. Finally, research strongly suggests that to be effective, measurement of sustainability impact must be easy [17–19]. Community Sustainability Assessment Tools (LEED (Leadership in Energy and Environmental Design), HQE (High Quality Environmental standard), etc.) are highly complicated to use and manage and they are not working [20]. A second problem is that communities are unlikely to invest in collecting data on sustainability indicators unless monitoring is linked to action that provides immediate and clear local benefits [21,22].

In this context, this paper, using one sustainability metric and associated target improvement levels (energy reduction), seeks to not only demonstrate the significant economic and environmental value of sustainability to the local community, but more importantly to show that specific sustainability goals can be tailored to a local community for greatest impact. This optimization of local sustainability goals/targets is shown to be enabled from greater data granularity; in this case, from use of building specific historical energy and building data from throughout the community. Additionally, this paper seeks to show that greater data granularity illuminates nonlinear community-wide economic and environmental impact with target improvements, and by doing so, shows the value in strategic worst-to-first (WF) investment strategies (see Section 2.2 for more detailed explanation about WF) to realize greatest impact.

2. Methodology

Two main research questions are posed for this study; 1) If we know the spectrum of building energy effectiveness and cost effectiveness of energy reduction as well as the manufacturing base within a community, can a more accurate assessment of economic impact of energy reduction in a community be developed? 2) What is the community-wide economic and environmental impact of a targeted energy reduction based upon a ‘worst to first’ (WF) strategy, and will the local manufacturing benefit from the strategy? Fig. 1 shows the general methodology employed, combining historical community-wide building energy and building data with local economic input–output data, thus enabling estimate of economic impact due to energy reduction for targeted measures having the greatest local economic impact. The following sub-sections detail each block described in Fig. 1.

2.1. Historical community-wide energy data and an energy model

Historical energy data can be 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 (PRInceton Scorekeeping Method) approach [23] can be 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 can be established in each energy category for each building type. Each building can be compared to the appropriate benchmark. Simple energy models can then be established for each building and residence [24–26]. These models are based upon the following framework. With heating/cooling energy intensity (MJ/m^2) estimated, the residences can be compared against benchmark heating/cooling energy intensity for comparable residences. High heating/cooling energy intensity residences in comparison to the benchmark are assumed to have both poor heating/cooling system efficiencies and envelope thermal characteristics. Whereas, low heating/cooling energy intensity residences are assumed to have high efficiency heating/cooling systems and low energy envelope characteristics. The residence models developed assume a functional relationship between the residence's energy characteristics and the difference between the heating/cooling intensity to the benchmark heating/cooling intensity. These characteristics are bound minimally and maximally to the worst and best characteristics in practice. Ultimately, the models developed for each residence yields a predicted typical weather year energy intensity equal to that measured. The savings potential in all energy categories for each residence, along with the simple payback, can then be estimated.

2.2. A worst-to-first (WF) investment strategy

Generally, analysis of the savings benefits from investment is restricted to the energy costs savings each individual residence yields from investment. Utility rebate programs for example do not differentiate between customers. Rebates are offered equally to all

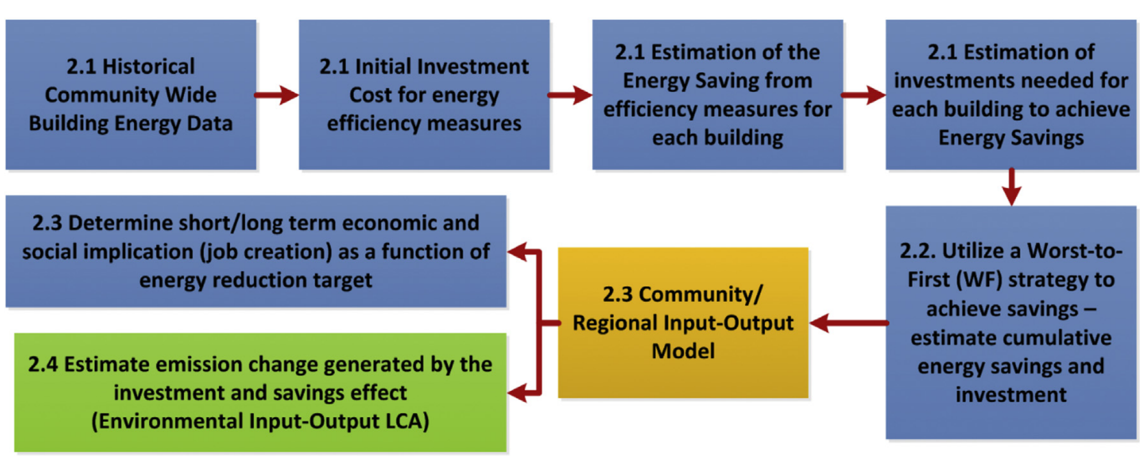

Fig. 1. Flow diagram of proposed research methodology (each block explained in the following subsections).

Please cite this article in press as: Choi J-K, et al., Economic and environmental impacts of community-based residential building energy efficiency investment, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.10.082