A COST BENEFIT ANALYSIS OF RETROFITTING PUBLIC POLICIES ON ATLANTA RESIDENTIAL HOUSING

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Abstract

The residential building sector has a major share in carbon emission and energy consumption. In the US, around 60% of the housing stock belongs to the owner-occupied sector. Since more than half of the existing building stock was built before the modern energy efficiency standards are taken place, there is a potential to reduce the energy consumption and greenhouse gas emissions in this sector, only by retrofitting the existing buildings. However, this goal cannot be achieved without a larger scale Cost Benefit Analysis (CBA) to develop and demonstrate market ready retrofit solutions/policies from both the government and the homeowner's standings. To this extend, the aim of the presented paper is to conduct a city-level CBA on the city of Atlanta which ranked 5th in producing GHG emissions among 100 US metropolitan areas while residential buildings sector is ranked 4th among other contributing sectors. To this end, a hypothetical public policy of retrofitting single-family residential buildings built before 1970s is proposed with the objective of reducing the regional energy consumption rate while calculating the upper bound of the tax to be proposed on the properties rejecting to renovate. The preliminary results of this CBA revealed that although retrofitting all the prior 1970s buildings won't be beneficial comparing to the status quo, the numbers are highly sensitive to the proposed discount rate as well as the percentage of the homeowners practically decide to retrofit. The sensitivity analysis showed that if only 30-40% of participants decided not to renovate and pay the tax, the CBA could be a positive Net Present Value (NPV) with a relatively low tax rate (less than $0.5/sqft) implementation. Therefore, it is recommended to more accurately study the reaction of the homeowners to the policy before implementing the tax/subsidy rates while precisely observe the fluctuations of the market discount rate.

Keywords

Cost Benefit Analysis, Retrofitting Public Policies, Residential Housing, Decision Analysis

Introduction and policy definition

One of the major concerns in the emerging era of sustainable cities and urban resiliency is to reduce the overall energy consumption and associated environmental impacts. According to the 2018 US energy flow chart, the residential building sector accounts for more than 10% of the total US energy consumption (Lawrence Livermore National Laboratory, 2018). Since most of the existing residential building stock was built before the implementation of energy efficient codes and regulations in the US, there is a potential to reduce the energy consumption and consequential emissions in this sector, only by retrofitting the existing buildings. To this end, the authors chose Atlanta which was identified as one of the top producers of Greenhouse Gas (GHG) emissions among 100 US metropolitan areas (Markolf *et al.*, 2017), and assessed the implementation of a hypothetical public policy of retrofitting single-family residential buildings built before 1970s in this region. 1970s was chosen as the transition decade because the state of Georgia began to implement building restrictions on the residential construction to save energy starting from 1970s (Aroonruengsawat and Auffhammer, 2012).

Due to the data limitation, the Fulton county is selected to test and validate the policy implementation and the Cost Benefit Analysis (CBA). Fulton county is among one of the nine major counties that together, form the Atlanta metropolitan area. However, this county by itself, covers 90% of the City of Atlanta. The objective of the proposed policy is to reduce the regional energy consumption rate while calculating the upper bound of the tax threshold to be implied on the properties deciding not to renovate. The costs and benefits of implementing the proposed public policy is then compared with the status quo which is leaving the buildings as is.

CBA is a method for assessing the net benefits of a project or proposal relative to other alternatives, typically the status quo (Boardman, 2011). It is generally calculated by subtracting the monetary value of the total costs from the total benefits of the project or policy implementation practice. Most of the governments including the US and the Australian government are committed to the use of CBA to assess regulatory proposals in order to encourage better decision making.

The first step before conducting a professional CBA is to define the standings, meaning that whose benefits and costs should be included in the analysis. In this regard, the residents and the local government were identified as the standings for the proposed public policy. The next step is to identify the physical impact categories of the proposed policy, catalogue them as benefits or costs, and specify the measurement indicator of each impact category. A detailed explanation of the assumptions and ground rules used to perform the policy implementation are demonstrated in Table 1.

Table 1: CBA assumptions and ground rules

Numbers	Assumptions and ground rules
1	Local government pays for the subsidy and program administrations
2	Horizon of the project is selected to be 30 years based on the average replacement time for insulation materials (Athena, 2002)
3	Retrofit costs are averaged numbers from actual similar projects conducted in Atlanta (Jackson *et al.*, 2012)
4	Residents must pay tax if they don't retrofit
5	Residents will receive 20% of the renovation cost as a subsidy from local government based on a similar policy in Poland (Gerőházi and Szemző, 2016)
6	Retrofit options apply to all buildings including the attic/knee wall insulation and the foundation insulation (Jackson *et al.*, 2012)
7	People live in their homes during renovation period as it will happen zone by zone
8	10 cents per square footage is the monetary benefit of satisfaction for houses that retrofit
9	Local government will issue free renovation permit to those who retrofit
10	Discount rate assumed to be 8% based on the appropriate discount rate for residential real estate analysis in Atlanta
11	Electricity rate in Atlanta is $ 0.056582 per kWh based on the Georgia power declaration rates
12	52 kilograms of energy-related carbon dioxide per million Btu for Georgia is assumed based on the Energy Information Administration (EIA) 2018 report (US Energy Information Administration, 2018)
13	All construction and administration processes will happen in the first five years of the policy implementation project
14	Inflation rate is 2.13% based on the average inflation rate of Georgia in 2016 (Plecher, 2016)
15	Decisions of whether to retrofit or not will happen at the beginning of the policy implementation project

Benefits and costs impact valuation

The next step in conducting a CBA is to identify the impacts of the proposed policy on all the standings and categorize the impacts into costs or benefits. In the proposed policy, the benefits and costs of the standings were identified and presented in Table 2.

Table 2: Benefits and costs identified for the standings

Standings	Benefits	Costs
Residents	Potential saving on utility bills if retrofit Better living quality if retrofit	Cost of retrofitting
Local government	Tax revenue from those who do not retrofit Reduce regional CO2 emission	Provide subsidies on retrofit Program administration

In a CBA that analyses a change in government policy, all the associated costs need to be sum up and subtract from all the benefits resulting from the policy. Doing this requires that the values of all these benefits and costs are measured in monetary terms (Boardman, 2011). However, the most intuitively important impacts (e.g. environmental impacts) are sometimes difficult to value in monetary terms. In the following paragraphs, the models and secondary data sources used to monetize the identified impacts of the proposed public policy are discussed in detail.

Benefit 1: Savings on utility bills

The amount of annual energy savings after retrofitting were calculated as 11,300 BTU per square feet per year which is averaged on energy savings of similar case studies that took place in the region. The mentioned case studies were conducted by researchers at Oak Ridge National Laboratory (ORNL) in collaboration with Southface on comprehensive energy retrofits implementation on Atlanta dwellings (Jackson *et al.*, 2012). Additionally, the numbers were monetized using the $0.056582 per kWh electricity rates extracted for Atlanta from the Georgia Power webpage (Georgia Power, 2019).

Benefit 2: Reduction in carbon emissions

The average social cost of one ton of carbon dioxide emission is extracted as $20 from the shadow price values presented as valuation of impacts in the most referenced CBA textbook (Boardman, 2011). Additionally, the energy-related carbon dioxide emission is extracted as 52 Kg CO2 /MMBtu from the US Energy Information Administration (EIA) 2018 report (US Energy Information Administration, 2018). Using the mentioned numbers, the monetary value of carbon emission associated with the energy savings through retrofitting was calculated and used for the CBA study.

Benefit 3: Living satisfaction

This impact is valued and calculated completely based on pre-defined assumptions. As mentioned in Table 1, 10 cents per square footage assumed as the monetary benefit of satisfaction for houses that retrofit in every year. The idea is based on home-owner's expression of interest in saving energy and emissions for their society as well as the satisfactory feeling of living in an upgraded and more energy efficient house.

Benefit 4: Tax revenue

Since the proposed public policy is a hypothetical policy without any direct feedback from the government, the authors decided to keep the tax revenue as a variable and calculate the minimum revenue which the local government can expect from implementing the policy in order to receive zero net benefit. Therefore, this benefit is considered as a changing variable in the CBA study and further discussions around the feasible numbers are presented in the sensitivity analysis section.

Cost 1: Cost of retrofit

The cost of retrofitting was extracted and averaged from the same ORNL project (Jackson *et al.*, 2012) using case studies on houses built before 1970s in Atlanta which were renovated only for attic/knee and foundation insulation. Based on their results, the average of $4.7 per square feet is calculated for retrofitting the similar buildings in the region.

Cost 2: Subsidy costs

As mentioned in Table 1, based on similar policy adaptations in Poland (Gerőházi and Szemző, 2016), 20% of the retrofitting cost is assumed to be covered by the government as a subsidy to support the retrofitting policy. This will result in $0.94 per square feet of subsidy cost for the government.

Cost 3: Program administration costs

The administration cost of implementing the policy is calculated based on assumptions mentioned in Table 1. Particularly, the study considered the requirement of 10 people working fulltime on the average salary rate of $20/hr during the timeframe of the project which is assumed to be 5 years of continuous work for the complete implementation of the tasks.

Urban scale monetizing of the impacts

Finally, to convert all the monetized costs and benefits calculated previously into an urban scale analysis, the total number of single-family residential buildings in Fulton county including the buildings' footprint were extracted from various available data sources including the Zillow real estate (Zillow, 2019) as well as the Fulton county property tax (Fulton County Tax Commissioner, 2019) webpages. The results were then separated by the building's vintage for further urban-level CBA investigations. The data analysis revealed the total amount of 16,313,754 square feet of single-family residential buildings built only over 1970s (built between 1970 to 1979) and the total amount of 172,789,527 square feet of single-family residential buildings built before 1970.

In the next step after expanding the benefits and costs to an urban scale, the assumed inflation rate of 2.13% was used to monetize the total impacts throughout the whole life cycle of the project. This means that the benefits of retrofitting were assumed to be impactful over the 30 years of life cycle whereas the costs of the policy implementation were assumed to be distributed over the 5 years of the practical policy administration procedure.

Discounting and results

Most significant policies and projects have long term consequences that unfold over time. Therefore, it is essential to conduct an inter-temporal comparison of monetized impacts or discounting in a CBA study. Discounting is the adjustment of future impacts to a common metric. The general equation of discounting is presented in Equation 1. In this equation, Present Value (PV) represents the value today and Future Value (FV) represents the value at an interval "t" in the future. Additionally, "r" represents the interest rate in this equation.

$$FV = PV\,(1 + r)^t$$

Equation 1

Generally, for discounting in CBA studies, the Net Present Value (NPV) of different alternatives are calculated using Equation 2. For this purpose, each year must be separately discounted, and the total numbers are sum up to calculate the PV of the impacts.

$$NPV = PV(Benefits) - PV(Costs)$$

Equation 2

In this CBA case study, the discount rate of 8% is assumed based on the appropriate discount rate for residential real estate analysis in Atlanta. Using the assumed discount rate and taking all the ground rules mentioned in Table 1, the NPV of retrofitting every single-family residential building in the City of Atlanta turned into the negative number of ($102,782,318.43). This means that the costs of implementing this policy in a full urban-level scale significantly outweigh the benefits.

Sensitivity analysis

Although the initial proposed policy failed the CBA, it is important to notice that the CBA is only as good as the assumptions and ground rules. There are several variables and unknowns that might critically change the results including technology changes, operating environment as well as consumer preferences. For this reason, there may be considerable uncertainty involved in both the predicted impacts and the appropriate monetary valuation of each unit of the impact. To this end, sensitivity analysis is used in CBA studies to deal with such uncertainties.

One of the main uncertainties involved in the proposed public policy is the reaction of the homeowners to the policy. Although the current CBA study considered that everyone will retrofit their old houses, it is not the case in real world scenarios. To reflect this in the analysis, the authors considered various percentages of homeowners who practically accept to renovate. Hence, the authors re-ran the CBA multiple times with different portions of people accept to retrofit, considering the tax revenue as a variable and the NPV to be zero. The results are shown in Table 3. In this table, the "proportion retrofitted" represent the percentage of the homeowners with houses built before 1970s, who decide to retrofit their buildings.

Table 3: Sensitivity analysis on percentage of homeowners accept to retrofit

Portion Retrofitted	Total (retrofitted) sqft	Remaining (taxable) sqft	Tax Revenue ($/sqft)	NPV
Status quo	-	-	-	0
10% retrofit	17,278,952	155,510,574	0.08	0
20% retrofit	34,557,905	138,231,621	0.16	0
30% retrofit	51,836,858	120,952,668	0.26	0
40% retrofit	69,115,810	103,673,716	0.41	0
50% retrofit	86,394,763	86,394,763	0.60	0
60% retrofit	103,673,716	69,115,810	0.90	0
70% retrofit	120,952,668	51,836,858	1.40	0
80% retrofit	138,231,621	34,557,905	2.39	0
90% retrofit	155,510,574	17,278,952	5.36	0

All built before 1970	172,789,527	0	0	(102,782,318)

Based on the results in Table 3, the tax revenue increases linear, as the percentage of participants in the retrofit plan increases. The reason behind that is the increasing cost of retrofitting (by providing subsidies) impose higher monetary pressure on the government and therefore, the government must increase the taxes in order to compensate the additional cost and keep its NVP on zero. In the extreme case of 90% retrofit, the government would be left with only 10% of the houses for taxing. Considering an average house with 1200 square feet area, the homeowner is required to pay the approximation of $6000 if decided not to retrofit. It is obvious that for less volume of householders decided to retrofit, the tax rate decreases.

In another scenario, it is of interest to study the effectiveness of the imposed policy, if buildings from different vintage are targeted. In this sensitivity analysis, it is assumed that every targeted household participates in the retrofit plan. The results are summarized in Table 4. The results showed that for all scenarios, the NPV is still negative. It is also noted that there is a significant jump in the value of NPV from1960 to 1950, as well as from 1930 to 1920, that worth further analysis. For instance, due to the huge increase in the total square footage of the buildings built during 1920s and 1950s, it worth imposing more detailed policies considering the exact vintage of the building.

Table 4: Sensitivity analysis on imposing policy based on building vintage

Policy to retrofit	Total sqft	NPV
Built < 1970	172,789,527	(102,782,318)
built < 1960	138,157,814	(82,527,152)
built < 1950	74,743,028	(45,437,533)
built < 1940	54,805,757	(33,776,755)
built < 1930	37,210,979	(23,486038)
built < 1920	8,812,742	(6,876,666)
built <1910	3,362,196	(3,688,787)

Another uncertainty involved in the proposed CBA, is the exact amount of discount rate at the time. It is of interest for the policy maker to find out the break event point for the discount rate, to make the renovation decisions economically feasible. In this essence, the next set of sensitivity analysis runs by altering the discount rate. The results are summarized in Table 5. The analysis is performed representing the case in which all buildings decide to retrofit. The results revealed that for discount rates of 6.5% or lower, the retrofit is an economically feasible option, but if the discount rate is 7% or above, the incurred cost outperforms the gained benefits.

Table 5: Sensitivity analysis

Policy to retrofit	Discount Rate	NPV
Built < 1970	8%	(102,782,318)
Built < 1970	7.5%	(71,340,889)
Built < 1970	7%	(36,623,839)
Built < 1970	6.5%	1,737,450
Built < 1970	6%	44,157,835
Built < 1970	5.5%	91,104,746
Built < 1970	5%	143,105,469

Conclusion and discussion

In this paper, the authors conducted a CBA on a hypothetical public policy to better understand the larger scale economic aspects of a retrofit plan devised on an urban level. Based on the proposed policy, all the single-family residential buildings of before 1970s, must either participate in the program and retrofit the house or pay additional taxes on rejecting the policy. Due to the time difference between the incurred costs and the gained benefits, the NPV technique is used to evaluate different items on an indifferent basis.

The results of this analysis revealed that although the initial proposed policy is not economically feasible, a proper tax rate implementation along with a feasibility study of the actual number of homeowners decide to participate, could significantly change the outcome. Additionally, as it is shown in the discount rate sensitivity analysis, the results are highly dependent on the discount rate. Hence, it is highly recommended to make sure to remove any potential uncertainty from the discount rate variable. Therefore, with a precise estimation of discount rate and number of households willing to retrofit, this policy could achieve its highest NPV, by correct assignment of the tax rates for those who won't retrofit.

On the other hand, it is anticipated that the best solution is to prepare a survey among targeted households and have an estimation of the portion of the participating households who will decide to renovate. The results of the sensitivity analysis showed that if only 30-40% of participants decided not to renovate and pay the tax, this could be a positive NPV with a relatively low tax rate (less than $0.5/sqft) implementation.

From practical perspective, it can be discussed that the retrofit option is associated with some discomfort during the renovation operations. The discomfort directly depends on the level of renovation, time of the year, etc. On the other hand, once the renovation is finished, the tenants will enjoy the renovated building (partially or fully), which lasts longer than the renovation period. Considering both comfort/discomfort and economical analysis, it is recommended for the governmental body and policy making firms to deliver appropriate information, along with economical incentives, to the home owners to expect higher participation rate in retrofit plan in the community.

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