

Developing tools for municipalities to meet carbon targets

Khosro Lari, Kevin Cant, Ralph Evins

2023

Faculty of Engineering and Computer Science

Faculty Publications

© 2023 Lari, Cant & Evins. This is an open access article distributed under the terms of the Creative Commons license CC BY: <https://creativecommons.org/licenses/by/4.0/>

Original citation:

Lari, K. Cant, K. Evins, R. (2023) Developing tools for municipalities to meet carbon targets. *Journal of Physics: Conference Series*, 2600. <https://doi.org/10.1088/1742-6596/2600/8/082014>

Downloaded from UVicSpace Research & Learning Repository

dspace.library.uvic.ca



University
of Victoria

Libraries

Developing tools for municipalities to meet carbon targets

Khosro Lari^{1*}, Kevin Cant¹, Ralph Evins¹

¹ Energy in Cities Group, Department of Civil Engineering, University of Victoria, Victoria, BC, Canada

* Corresponding author kh.lari@gmail.com

Abstract. Carbon emissions must be cut in half by 2030 to meet the Paris Agreement's goals, and cities and municipalities are at the forefront of the fight against climate change. In 2017, the energy use of buildings directly accounted for 51% of emissions in the City of Victoria and offered the greatest opportunity for the municipal government to act. Unfortunately, at this point, many cities and municipalities lack the tools and locally relevant data to make effective policy decisions. This research aims to develop a practical framework for analyzing and comparing the carbon impact of policies enacted by municipal governments, and is specifically focused on the energy consumption, and operating and embodied carbon related to single-family dwellings (SFDs) in the City of Victoria, which contains a heterogeneous building stock with construction dates ranging between 1860 to present day. The underlying model has been developed based on statistical modeling and agent-based behavioral responses to different policy actions. The agent-based modelling approach models stock development in terms of new construction, retrofit, and replacement by simulating individual decisions at the building level. The results can be used to identify optimal efforts to minimizing barriers or bottlenecks in achieving low-carbon ambitions while understanding or addressing related aspects such as housing affordability. Municipalities can use the dashboard to identify and prioritize climate solutions that meet their stringent obligations.

1. Introduction

The 2020s are a make-or-break decade for addressing climate change. In line with the Paris Agreement's goals, many cities have set ambitious targets to reduce carbon emissions. Cities and municipalities are at the forefront of the fight against climate change, and their policies can have a significant impact on reducing emissions. One of the biggest contributors to emissions in cities is buildings. The building and construction sector accounted for about 39% of the process related carbon dioxide emissions in 2018 [1]. In the city of Victoria, British Columbia, 51% of end-use GHG emissions are generated from buildings [2], emphasizing the importance of addressing building-related emissions to meet climate goals.

There is a wealth of literature addressing different aspects of decision-making and behavior change related to building retrofit and energy efficiency. Gamtessa [3] explains residential energy efficiency retrofit behavior in Canada using a theoretical framework that incorporates individual, social, and contextual factors. Lee and Hong [4] use a hybrid agent-based modeling approach to analyze rooftop solar photovoltaic adoption by integrating geographic information and data mining techniques. Lu et al. [5] propose a behavior-based decision-making model for energy performance contracting in building retrofit, which incorporates factors such as perceived benefits, risks, and social influence.

Myers and Souza [6] evaluate the effectiveness of social comparison nudges without monetary incentives in promoting energy savings behavior using home energy reports. Nägeli et al. [7] assess



policies to decarbonize the Swiss residential building stock using an agent-based building stock modeling approach, which incorporates factors such as technology diffusion, energy prices, and policy instruments. Nägeli et al. [8] in another work, propose a bottom-up modeling approach for agent-based building stock modeling, which considers long-term dynamics affecting the energy and climate impact of building stocks.

The research addressed in this paper aims to develop an easy-to-use dashboard-hosted tool that will provide municipalities and cities with a practical yet comprehensive framework for analyzing and comparing the carbon impact of policies enacted by municipal governments. The framework uses statistical methods and agent-based modeling, takes into account direct and indirect sources of carbon emissions from residential buildings, and accounts for risk and uncertainty while being driven by existing data sources. To the authors' best knowledge, the probabilistic methods for agent-based building stock modeling have not been used before. The tool will support decision-makers at the municipal level by providing anticipated results from different policy levers in a fast-responding and tactile manner. The dashboard can be used to identify optimal efforts to minimizing barriers or bottlenecks in achieving low-carbon ambitions while addressing related aspects such as housing affordability.

2. Methodology

This dashboard will be used to answer different questions like:

- *Where are we now?* Here we analyze the current status, mainly based on existing data sources, such as Canada's NRCan EnerGuide assessment database and British Columbia's Assessment property tax database. We present multiple options for policymakers to visualize, group, or graph the data. Also, we will present the current energy consumption, current carbon consumption, and current makeup of buildings.
- *Where do we need to go?* Here we visualize the targets in relation to the currently existing status (energy and GHG). We will compare residential energy and carbon to other major sectors'. And we will allow the users to set different targets for different dates to visualize the relative impacts.
- *How will we get there?* Here is the major research contribution. We present various retrofit options by age, size, archetype, fuel source, and other characteristics, include multiple retrofit packages. We will forecast construction rate with requirements for future performance targets of new homes. We analyze retrofit vs reconstruction of buildings. And we study the embodied carbon impact.
- *What will it look like?* Here the future results obtained from applying different policies will be shown. Results will be such as the comparison of graphs based on different targets and options.

Multiple stages used in this research to achieve above goals, including:

1. *Data Management:* In this stage several tasks are done such as cleaning, managing, and combining various existing datasets in order to analyze the energy consumption, operating, and embodied carbon related to single-family dwellings (SFD) in the City of Victoria.
2. *Statistical modeling:* This stage is the underlying model to match different databases with each other and for the calibration of the results. These statistical models include finding energy use and fuel types of the SFD buildings in the city of Victoria based on the EnerGuide database, among others.
3. *Agent-based modeling:* This is the main approach to model stock development by simulating individual decisions at the building level, such as new construction, retrofit, and replacement. In this part, multiple analyses are considered to obtain different aspects of the buildings such as energy, GHG, fuel type, cost analysis, payback period, probability of upgrades, and so on. These calculations are implemented for each future year based on the affecting input parameters, which can be used to see the effects of different policies.
4. *Dashboard-hosted tool:* The final stage is presenting all results and models in an easy-to-use dashboard to provide municipalities and cities with a practical yet comprehensive framework for analyzing and comparing the carbon impact of policies enacted by municipal governments.

The following flowcharts (Figure 1) show the detail parts of the Agent-Based Residential Retrofit Model used in this study to have a better view how this model predicts future results of the buildings based on different analysis and decision makings.

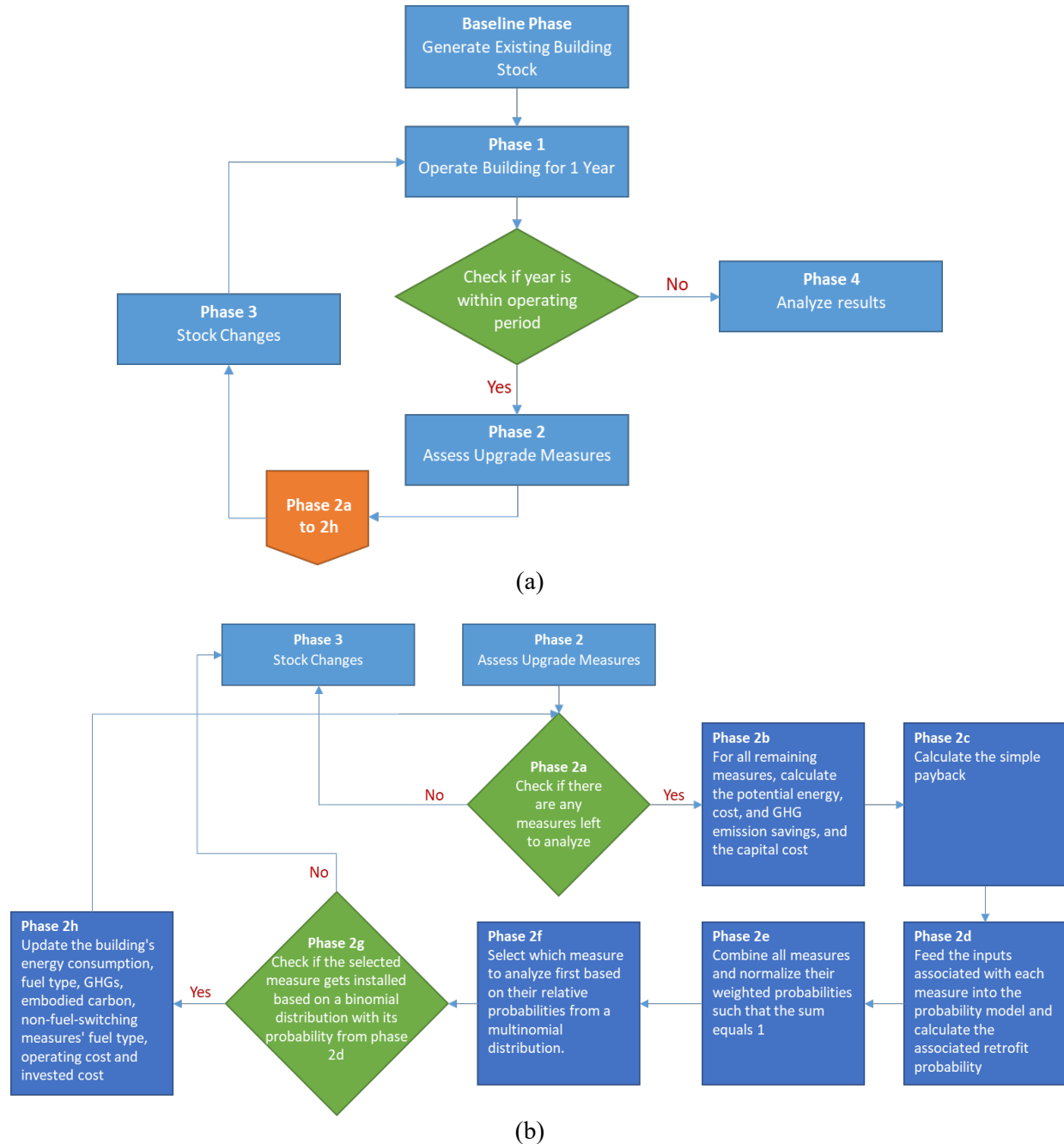


Figure 1. Flowchart of the Agent-Based Residential Retrofit Model

3. Results and Discussions

In this section, to conserve space only a subset of the results of the work are shown to highlight sections of this research.

3.1. Where we are now

This consists of results regarding the current state of the SFD building stock in the city of Victoria. Figure 2 shows the energy use of SFD buildings by fuel source, and figure 3 illustrates the operational GHG emissions based on the year range and floor area.

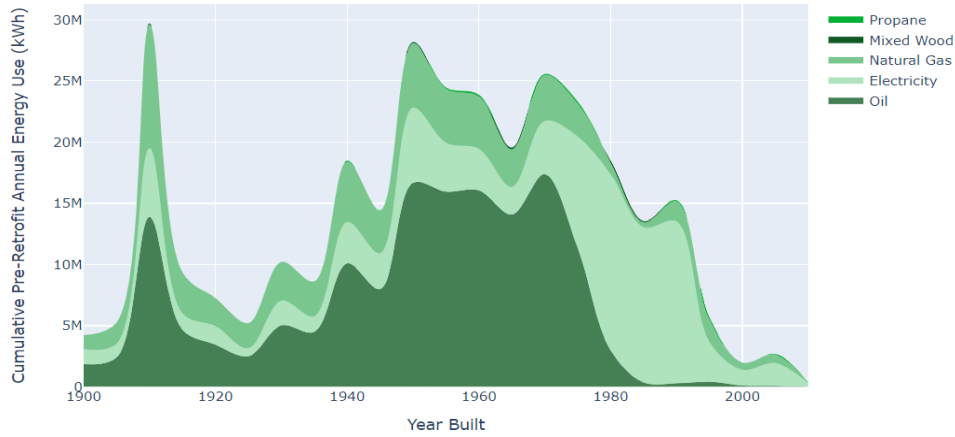


Figure 2. Cumulative annual energy use by fuel source

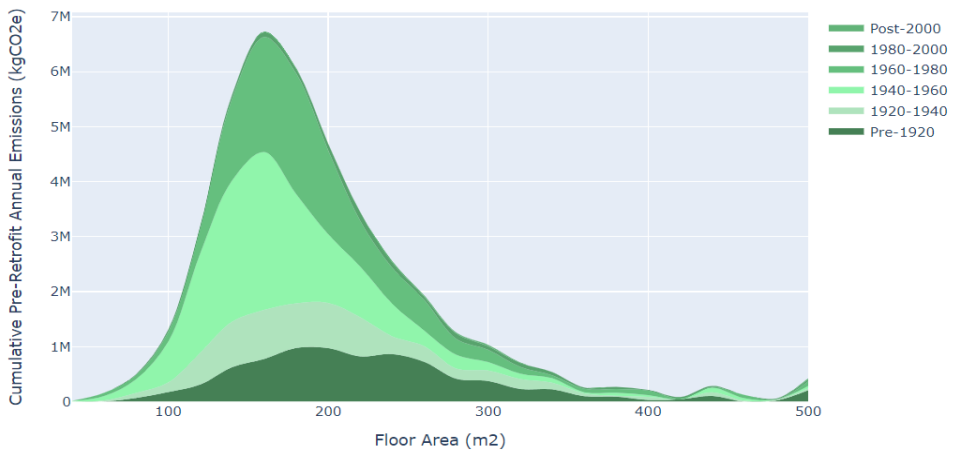


Figure 3. Cumulative annual emissions vs. year range and floor area

3.2. Where we need to go

In this part, the targets of energy and GHG in relation to the currently existing status are presented. Figure 4 shows the emissions targets for different dates.

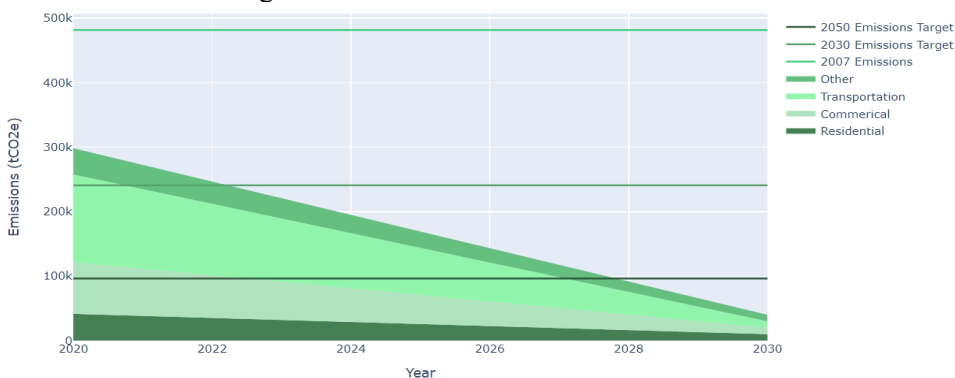


Figure 4. Emissions targets vs. year and sectors

3.3. What it will look like

This part presents the results indicating the future view of the city after applying different targets and options. The following figures shows some results based on the default input parameters of the model.

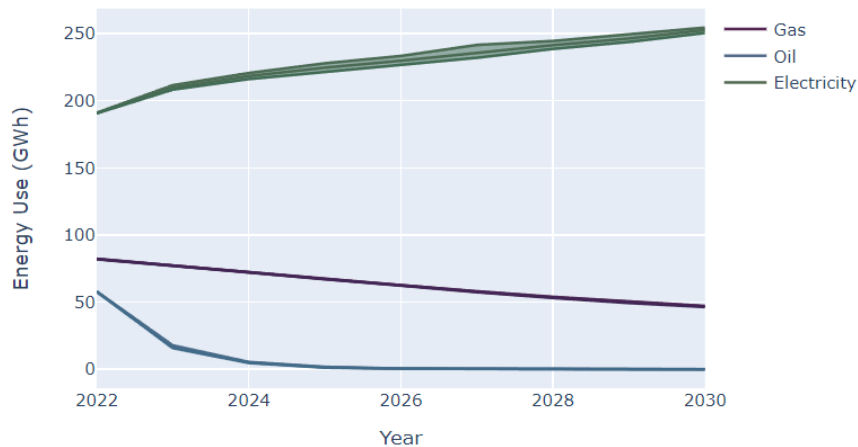


Figure 5. Annual energy use vs. year and fuel type

Figure 5 shows the total energy use of all SFD buildings in the city of Victoria by fuel type in each year from 2022 to 2030 after applying different retrofit incentive strategies to the buildings in each year. The change of fuel type percent of all SFD buildings are shown in figure 6 for each year. It is seen that the percent of buildings with electricity fuel type increases each year, while oil and natural gas fuel types reduce.

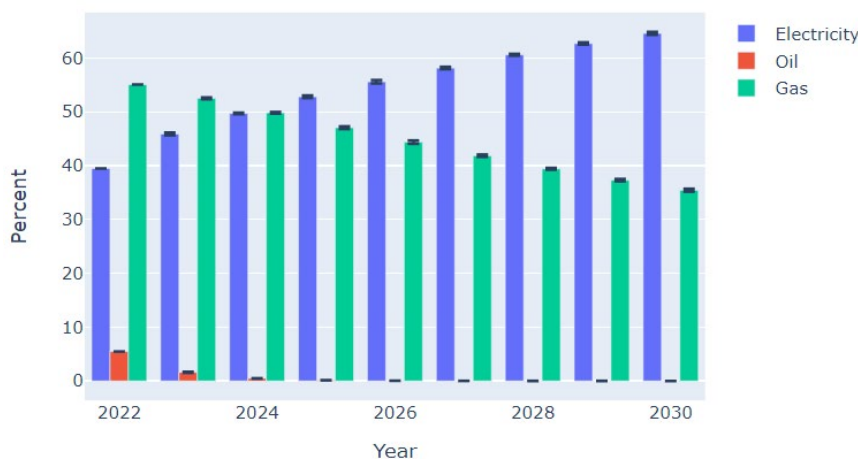


Figure 6. Percent of fuel types in each year

4. Conclusion

This paper has presented a framework for analyzing and comparing the carbon impact of policies enacted by municipal governments to reduce carbon emissions from residential buildings. The framework is designed to be simple and practical yet comprehensive and robust, and takes into account direct and indirect sources of carbon emissions from single-family dwellings in the City of Victoria. This tool was developed based on analyzing existing datasets. Cleaning, managing, and comparing the databases were the starting points. Then, machine learning and statistical modeling used to support outcomes. Finally, web-based tools were employed for interactive data visualizations in a dashboard environment that allows users to visualize and explore model outputs concisely and comprehensibly. Through the development of an easy-to-use dashboard-hosted tool, decision-makers at the municipal level can anticipate the results of different policy levers, identify optimal efforts to minimize barriers in achieving low-carbon ambitions, and address related aspects such as housing affordability.

Regarding the limitation of the tool, it should be mentioned that the current research focuses on the energy consumption, operating, and embodied carbon related to single-family dwellings (SFDs) in the City of Victoria. However, the tool has been developed in such a way that it can be replicated by

municipalities and cities worldwide if appropriate datasets exist. Also, the databases used to develop the dashboard may not be completely accurate, which will affect the output results. With this tool, cities and municipalities can take a significant step towards meeting the carbon reduction goals set forth by the Paris Agreement.

References

- [1] M. Santamouris and K. Vasilakopoulou, “Present and future energy consumption of buildings: Challenges and opportunities towards decarbonisation,” *E-Prime-Adv. Electr. Eng. Electron. Energy*, vol. 1, p. 100002, 2021.
- [2] “City of Victoria, Climate Leadership Plan: Strategies and actions for a prosperous, low carbon future,” 2018.
- [3] S. F. Gamtessa, “An explanation of residential energy-efficiency retrofit behavior in Canada,” *Energy Build.*, vol. 57, pp. 155–164, 2013.
- [4] M. Lee and T. Hong, “Hybrid agent-based modeling of rooftop solar photovoltaic adoption by integrating the geographic information system and data mining technique,” *Energy Convers. Manag.*, vol. 183, pp. 266–279, 2019.
- [5] Y. Lu, N. Zhang, and J. Chen, “A behavior-based decision-making model for energy performance contracting in building retrofit,” *Energy Build.*, vol. 156, pp. 315–326, 2017.
- [6] E. Myers and M. Souza, “Social comparison nudges without monetary incentives: Evidence from home energy reports,” *J. Environ. Econ. Manag.*, vol. 101, p. 102315, 2020.
- [7] C. Nägeli, M. Jakob, G. Catenazzi, and Y. Ostermeyer, “Policies to decarbonize the Swiss residential building stock: An agent-based building stock modeling assessment,” *Energy Policy*, vol. 146, p. 111814, 2020.
- [8] C. Nägeli, M. Jakob, G. Catenazzi, and Y. Ostermeyer, “Towards agent-based building stock modeling: Bottom-up modeling of long-term stock dynamics affecting the energy and climate impact of building stocks,” *Energy Build.*, vol. 211, p. 109763, 2020.