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Evaluation of financial incentives for green buildings in Canadian landscape

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ABSTRACT

Financial Incentives (FIs) for green buildings are a major component of energy policy planning and play a vital role in the promotion of sustainable development and carbon mitigation strategies. Despite the presence of numerous FIs in Canada, there is still a lack of understanding on their distribution and effectiveness. This review first investigates the FIs available for residential and commercial buildings in Canada, and then performs a comprehensive review of studies related to FIs' effectiveness evaluation. It is found that FIs for buildings in Canada can be distributed into four categories: tax, loans, grants, and rebates. Among these, rebates from utility providers are the most common and are administered in all provinces. In addition to these, special incentives are available for three end-users (low-income, aboriginal people, landlords and tenants) and for three types of buildings (heritage, non-profit and energy rated). A clear contrast is observed on FIs offered in three regulatory regimes (Federal, provincial and municipal). Four provinces (Alberta, British Columbia, Ontario and Quebec) are leading in green building efforts. The in-depth literature review was also used to develop an understanding on the criteria used in effectiveness evaluation and the factors impacting effectiveness. Based on the findings of different studies on FIs effectiveness, a generic approach for evaluation of FIs is proposed that can help in deploying successful FIs programs. The results of this review are of importance to the policymakers, government authorities, and utilities engaged in designing and improving FIs for energy efficient buildings.

1. Introduction

Climate change like COVID-19 pandemic is a global emergency; however, its negative outcomes are slower in materializing and have much graver impacts in the long run [1]. Greenhouse gases (GHG) from anthropogenic activities are a major driver for climate change. According to the International Energy Agency (IEA), the building sector is a significant contributor to the global GHG and accounts for more than one-third of annual emissions [2]. Making buildings more energy efficient can help address climate change. Financial incentives (FIs) are important and widely implemented policy instruments that can help to reduce buildings' energy and GHG emissions [3,4]. FIs[1] for making green buildings (GBs) can be in the form of grants, loans, rebates, and tax credits [3,5–7]. FIs assist in increasing the energy efficiency of buildings by removing financial barriers, penetration of innovative low-carbon technologies and/or helping the implementation of other policy instruments [8–11]. They are important in setting a stage for the implementation of more stringent bylaws and policies such as promoting higher building performance standards (e.g. net-zero energy buildings). Due to COVID-19, the impacts of existing FIs for buildings will become even more important since energy retrofitting and integration of clean carbon technologies in buildings are being seen as an ideal response to simultaneously pursue climate change mitigation and revive damaged economy due to the pandemic [12]. Therefore, successfully utilizing FIs in promoting GB is crucial to ensure minimum wastage of national resources with maximized outcomes.

Knowledge on a country's state-of-the-art FIs is needed to lay a solid foundation for further improvements in the effectiveness of its energy policy. Reviews on FIs are available for a number of countries. However, these reviews either focus on a single FI in a number of countries like the work by Shazmin et al. [13] on property tax incentives for a number of

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[1] The term "Financial Incentives" or "FIs" throughout the paper will refer to Financial Incentives for energy efficiency in green buildings unless stated otherwise.

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Nomenclature

CAC	Command and Control
CIMS	Canadian Integrated Modelling System
CMHC	Canada Mortgage and Housing Corporation
DSM	Demand-Side Management
EERE	Energy Efficiency and Renewable Energy
EPCs	Energy Performance Contracts
FI	Financial Incentives
GB	Green Building
GHG	Greenhouse Gas Emissions
GM	Grey Model
HELP	Home Energy Low-Income
HVAC	Heating Ventilation and Air Conditioning
IEA	International Energy Agency
LCA	Life Cycle Assessment
LEAP	Long-range Energy Alternatives Planning
LEED	Leadership in Energy and Environmental Design
MARKAL	Market Allocation
MBI	Market-based Instruments
MURB	Multi-unit Residential Building
NEMS	National Energy Modeling System
NPO	Non-profit organizations
NRCan	Natural Resources Canada
PBP	Payback Period
US	United States

Canada Provinces

AB	Alberta
BC	British Columbia
MB	Manitoba
NS	Nova Scotia
ON	Ontario
PEI	Prince Edward Island
QC	Quebec

countries including Canada, or they focus on policy instruments in countries other than Canada; example, Sebi et al. [14] work on incentives in Germany, France, and the US or Bertoldi et al. [15] work on financial instruments for residential buildings in Europe. Some recent reviews focus on policy instruments in a single country, such as G. Liu et al. [16] work on policy instruments (including FIs) in China. Alternatively, they look at FIs present for a particular energy upgrade, such as Curtin et al. [17] study on FIs present for low-carbon technologies (solar systems, heat pumps etc.). The existing literature predominantly focuses on policy instruments in the US, Germany, or China, and not specifically on the state of FIs in Canada. The limited studies that do consider Canada either focus on a particular building type, such as a study by Hoicka et al. [18] (residential building retrofits); focus on a particular program, such as work of Nadel and McMahon [19] on lighting energy, or are too old to extract meaningful results, such as Stern et al. [20] (performed in 1986). Overall, the published body of knowledge either focuses on specific FIs (e.g., tax incentive); specific buildings (e.g., residential); specific energy measure (e.g. heat pumps) or a specific stakeholder (e.g., the private-home owners); and a holistic examination of available FIs for buildings in Canada is still missing in the literature. Therefore, with a particular focus on Canada, this study attempts to take a closer look at the state-of-the-art green building financial incentives to lay a ground for designing future incentives while improving the existing incentive strategies.

"Effectiveness" is one of the most important criteria that determines the rate of success of applied FIs. Though a number of studies have evaluated the effectiveness of FIs, there is a diversity/disparity in how effectiveness is defined and evaluated. For instance, a recent review by Kerr and Winskel [21] covers the policy instruments related to private homes retrofits; however, the important area of impact on rented housing is not covered. Similarly, some studies focus on the effectiveness of a particular technology. For example, Liu et al. [22] determined the effectiveness of policy instruments related to monitoring technologies for public buildings in China. In order to make evidence-based decisions, a review of these studies is required. Despite a number of studies on effectiveness evaluation of FIs, there are limited review studies on the topic. Olubunmi et al. [3] performed a systematic literature review on the most common themes in GB incentives and identified the effectiveness of incentives as a major research area. However, their study did not provide an in-depth exploration of the types and methods used for measuring effectiveness [3]. Similarly, an appraisal study by Ürge-Vorsatz et al. [23] determined the effectiveness of 20 different policy instruments (including FIs), but the wide ranges of methods that can be used to measure effectiveness were not investigated. Therefore, a research gap exists regarding the important factors and the context that need to be considered for the evaluation of FIs' effectiveness.

Based on the identified gaps in literature, this paper aims to develop a deeper understanding on evaluation of FIs effectiveness for promoting green buildings in Canada. The main objective of this study is to fulfill the need for a comprehensive overview of (1) the state of FIs in Canada and (2) the FIs effectiveness evaluation methods and criteria. Compared to similar studies, this review provides an in-depth information on status of FIs in Canada and a spectrum of factors that contribute to FIs' effectiveness. This timely review can help in making policy recommendations based on the effectiveness of FIs among building stakeholders.

The remaining part of the paper proceeds as follows. Section 2 describes the methodology used for performing the review. Section 3 describes the types of green building FIs available in Canada while Section 4 describes the distribution of these FIs along Canadas' regulatory regimes. Section 5 provides a review on how effectiveness of FIs is being evaluated. Section 6 concludes the study with key findings and their policy implications.

2. Methodology

This paper aims to provide a comprehensive review of the state-of-practice of energy related FIs available for residential and commercial buildings in Canada and effectiveness evaluation of FIs in GBs. In order to achieve these objectives, a systematic review using the document analysis technique has been employed [24].

The methodology for this article involved the use of specific keywords, specialized databases, and document types that ranged from journal articles to books. A keyword search was conducted in two main bibliographic databases: Compendex Engineering Village and Web of Science. The literature published after 2010 was given a priority, so as to provide a more up-to-date status of the GB related FIs literature. Document analysis technique method used for this research involved the review of all forms of technical writings; for example, peer-reviewed articles, technical reports, conference publications, books and theses, that can help in evaluation. The number of peer-reviewed journals, conference proceedings, books, and other literature sources relevant to the field of GBs considered are shown in Fig. 1. In addition to these, various municipal, utilities, provincial and Natural Resources Canada (NRCan) databases were explored for determining the FIs available for residential and commercial buildings in Canada. This review provides an assessment of FIs in Canada implemented until 2018 unless new incentives come to the practice.

The literature is collected from articles of journals with high impact

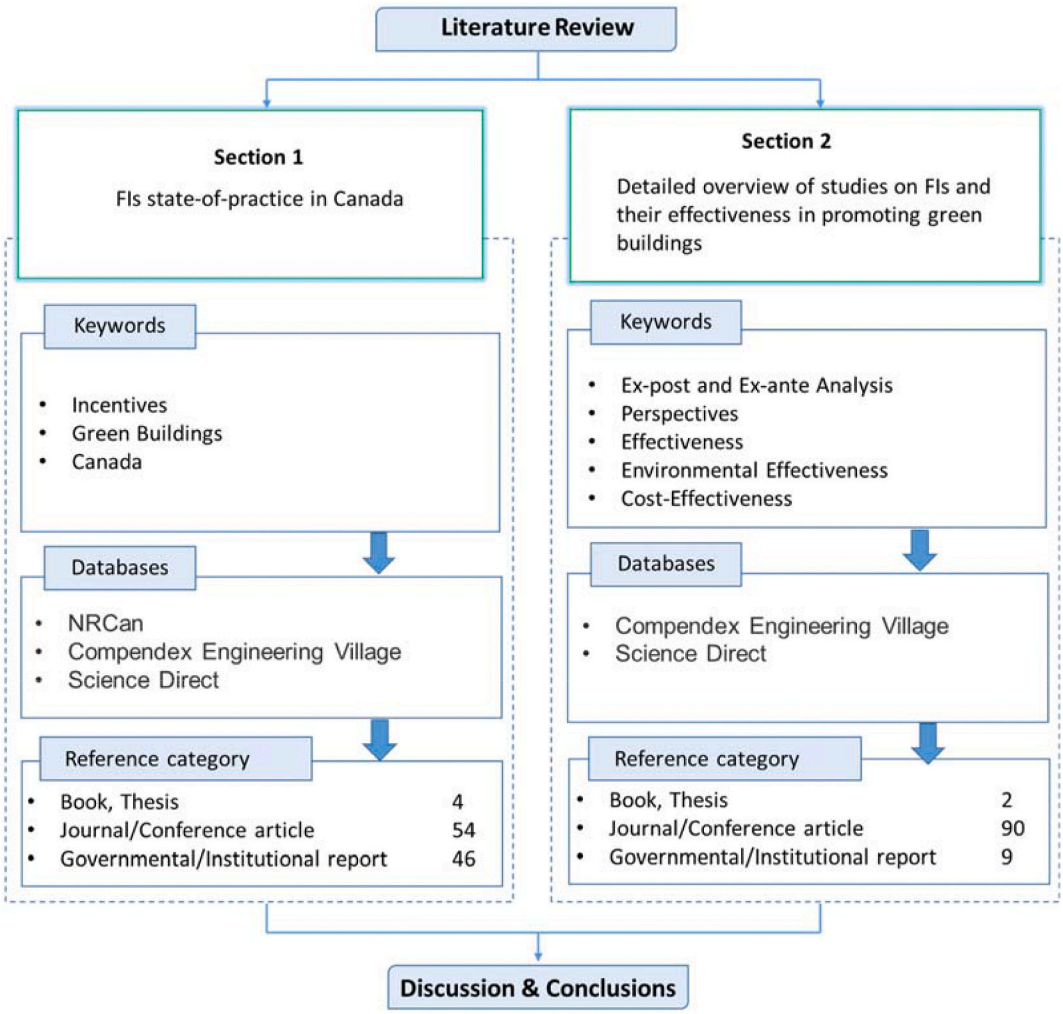

Fig. 1. Research methodology.

factors. The impact factor represents how frequently the scientific community is citing the journal [25] and this parameter is considered when comparing and ranking journals [26]. Journal articles with impact factors greater than 2.5 were prioritized in this study. Table 1 shows the journals that were cited more than twice in this review study along with their impact factors. In the research presented, the terms FIs, financial instruments, and the economic instrument are used interchangeably and represent the same meaning.

3. Canada's building energy efficiency landscape

The Paris agreement and the Pan-Canadian Framework have encouraged the federal and provincial governments in Canada to set carbon mitigation targets for the year 2030, which will ensure that the global temperature remains below the limit of 1.5 °C of the pre-industrialized levels. This demanding goal can be achieved through the application of effective energy efficiency measures in all sectors. Canada's building sector is a major consumer of energy and is responsible for up to 12% of the country's GHG emissions [27]. The majority of the energy consumed in the residential sector is used for space heating (64%) and water heating (19%) followed by electrical appliances, lighting and space cooling that use the remaining portion of energy [28]. The commercial sector accounts for 11% of the total energy consumption with the majority accounted by space heating (56%) followed by auxiliary equipment (14%) [28]. In the commercial sector, the largest consumers of energy are office buildings [29]. Furthermore, more than 80% of the existing residential and commercial buildings were made before 1996 and do not conform to the more stringent energy efficiency codes (such as NECB-2015 [30] and BC Energy Step Code [31]) for new buildings [27,32,33]. In Canada, the building sector's energy use continues to rise with the residential sector alone showing an 8% increase from 1990 to 2015 [34]. Moreover, researchers argue the potential of building sector of Canada to address climate change is underestimated and needs to emphasized especially for deep energy retrofits in next decade [35].

GBs yield numerous benefits that include lower operating costs, lower GHG emissions, a better quality of life for the occupants, higher occupancy rates, increase in real estate values and others [36–40]. All these factors establish the necessity of converting both existing and new buildings to GBs. Low energy GBs can be achieved by three types of

Table 1
Major journals used in the review.

Journal	5-year impact factor
Renewable and Sustainable Energy Reviews	12.348
Journal of Cleaner Production	7.491
Energy	6.046
Energy Policy	5.693
Energy Economics	5.790
Energy and Buildings	5.055
Technological Forecasting and Social Change	5.179
Building Research & Information	3.744
The Energy Journal	2.739

energy interventions: energy conservation, energy efficiency and energy saving measures [41]. New buildings can be designed to be green by developing better building thermal envelopes, using energy efficient equipment and appliances, and using renewable energy technologies [42]. Existing buildings can be improved through retrofitting, which includes improvements in the thermal envelope, use of energy efficient equipment and appliances, use of renewable energy technologies, as well as changes in human behavior [43,44]. Retrofitting for residential buildings yields maximum benefits when the roof and floor are insulated, the performance of glazing is improved, and renewable energy is used [44]. On the other hand, retrofitting of commercial buildings should focus on building envelope, lighting systems, and improvements in HVAC systems for more benefits [44,45]. Ownership structures of residential and commercial buildings vary significantly, leading to the involvement of different stakeholders responsible for energy efficiency improvement (Fig. 2). Stakeholders related to residential buildings in Canada are building owners in a majority of cases, while for commercial buildings the investor will vary depending on the size and the intended use of a building. As an example, for small commercial buildings, the majority of the energy improvements are managed by owners while for large buildings professional energy managers are involved [46]. Hence, the success of FIs for green building can be assured only if the necessary factors and the stakeholder context is kept in mind during evaluation.

3.1. *Financial incentives for green buildings*

A multitude of different policy tools are available that can help in the market penetration of GBs and achieving energy reduction targets. Policy tools can be divided into two groups: (1) Regularity or Command and Control (CAC); and (2) Market Based Instruments (MBI) [47–49]. CAC provides legislation defining the legal limits; for example, energy efficiency regulations [49]. MBIs are considered to be more powerful than CAC as they offer some form of incentive to the user [47]. MBIs can be sub-divided into three categories: market friction reduction, rights-based and price-based [50]. Table 2 gives a description of these instruments while Fig. 3 provides examples of MBI available for the promotion of GBs in Canada.

FIs are the types of price-based MBIs that are provided extensively from government and utility providers. A brief description of different types of FIs is provided in Table 3 while the applications of these instruments in the Canadian context are provided in sub-sections 3.1.1 to 3.1.3. It should be noted that among the policy instruments described in this section, no single policy instruments can be considered as a silver bullet for achieving a country's carbon mitigation goals and the effectiveness of an instrument changes with respect to context.

3.1.1. *Subsidies*

Price-based or financial instruments can be in the form of subsidies, rebates, and dis-incentives. The subsidies can be provided in the form of loans, tax-allowances or grants [55].

Loan incentives: Loan incentives are a common type of FI offered both by governmental organizations and commercial banks [17,62]. Loans for GBs typically charge a lower interest rate over a longer duration compared to other commercial loan [62]. The amount of loans offered vary from time to time and depend on macroeconomic conditions [63]. A list of GB loan incentives present in Canada is provided in Appendix

Table 2
Categories of market-based instruments.

Category	Description	Instrument examples	Ref.
Market friction-based	Market friction-based instruments help in achieving policy targets by improving the conditions of existing private markets. These MBIs are non-financial in nature	- Eco-labelling - LEED Standards - Energy Star ratings of appliances	[49, 51–54]
Rights-based	Rights-based or quantity-based instruments specify the amount of emission permitted under a specified condition	- Cap-and-trade scheme for provinces (emissions, quotas, or permits) - Carbon offset scheme - Lead trading	
Price-based	Price-based instruments provide changes in prices in existing market conditions	- Subsidies on high efficiency appliances - Carbon tax on fossil fuel used	

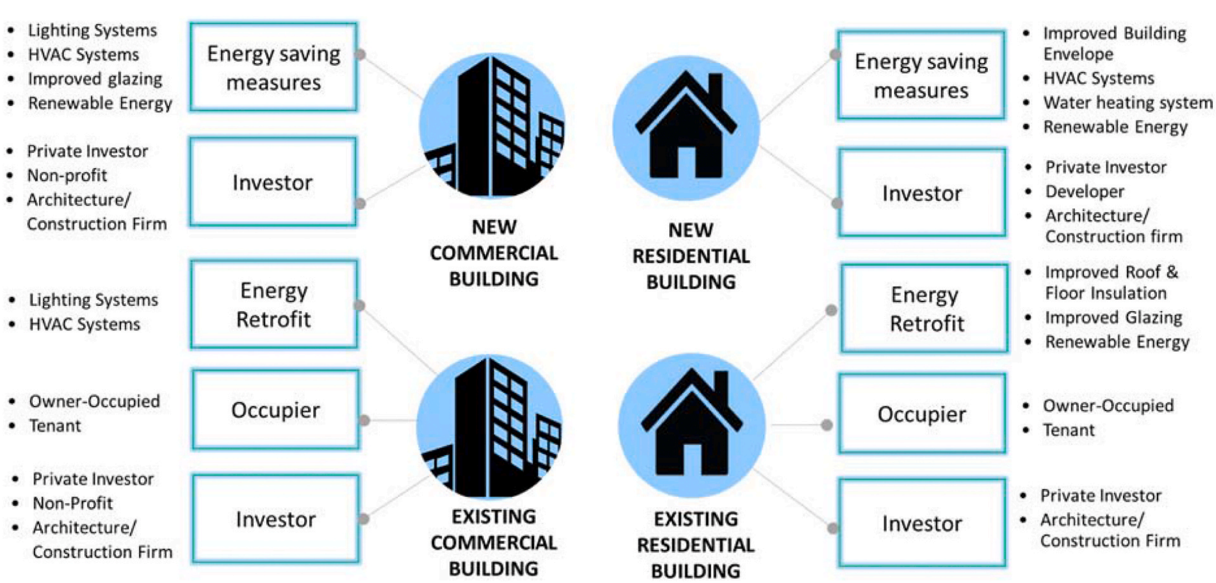

Fig. 2. Energy improvements and investors for residential and commercial buildings.

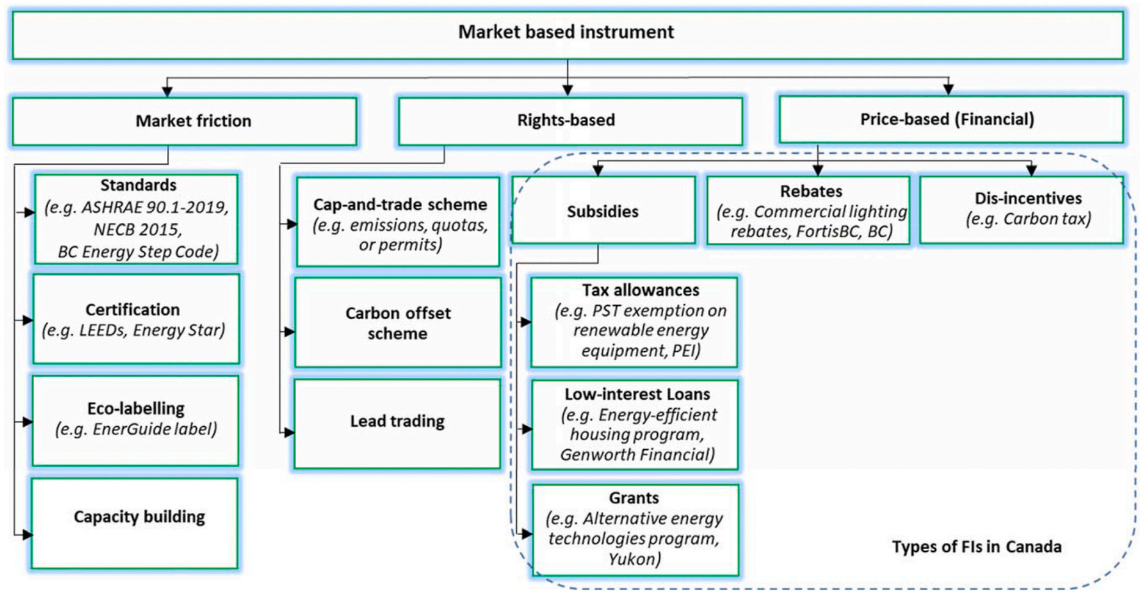

Fig. 3. Typology of market-based instruments for green buildings in Canada. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Financial incentives for green buildings.

Types	Description	Ref.
Financial Incentives	FIs are the monetary support provided by government or utility providers. Financial Incentives offered in forms of subsidies, rebates or disincentives require certain energy efficiency related conditions to be fulfilled by the investors.	[3,13]
Subsidies	Subsidies are offered on energy upgrades/retrofits that enable investors to perform energy upgrades at a lower rate than market price. The subsidies can be in the form of grants, loans or taxes.	[55]
Loans	Loan incentives are used to enable installation of an energy retrofit or energy efficient equipment at a low-interest rate. Low interest enables the viability of a larger number of retrofits compared to the higher interest rate.	[56, 57]
Grants	Grants are the monetary incentives that do not require to be paid back and are popular due to their simplicity. Grants account for a large sum of money and usually offered by the government at the federal level.	[17, 58]
Tax incentives	A tax incentive can be defined as monetary credit, deduction or exemption on the tax required to be paid if the energy target/energy upgrade was not performed for the building.	[59]
Rebates	Rebate is the full or partial amount returned on the applied energy upgrade measure. The rebates are usually offered by utility providers on the purchase of energy efficient equipment.	[60]
Disincentives	Dis-incentives are financial instruments that work as negative reinforcement towards energy efficiency improvements. Carbon tax is one of the most common dis-incentive and has been found to be successful in mitigating carbon emission.	[61]

A.1. In Canada, loan incentives for GBs are offered by a number of institutions: Canada Mortgage and Housing Corporation (CMHC) [64], banks [65], utility companies (e.g. Heat Pump Loan by FortisBC [66], Power Smart Home Loan by BCHydro [67], Power Smart Residential Loan by Manitoba Hydro [68]), and municipalities [69]. The majority of the loans are offered for a five-year period. The amounts offered and interest rates vary from one loan incentive program to another. Loans are available for the construction of new homes [70], retrofitting of commercial buildings [71] and upgrade of individual systems; such as Residential Earth Power Loan - for Cold Climate Air Source Heat Pumps, Manitoba (MB) [68]. Compared to other provinces MB offers the largest number of loans for GBs.

Tax incentives: The tax incentives are one of the most popular GB incentive offered by the governments [72,73]. Tax incentives can be used either in the form of positive incentives that encourage GBs construction such as tax rebates, reductions, exemptions (or tax breaks), preferential tax rate, tax deferral, and tax reimbursement [74], or as disincentives to discourage unsustainable practices [65]. Compared to other energy efficiency related policy instruments such as increments in interest rates or energy prices, taxes provide swifter changes in energy use [74]. The bases of these incentives can also be used to include accelerated property tax assessments, rate of property tax assessment, and certification levels for GB [13]. Tax exemption incentives or tax breaks are provided to developers for a limited time period and scope. Compared to other countries Canada's incentives are based on the exemption model rather than rebates and/or reductions [13]. In Canada there are limited number of tax incentives for GBs (see Appendix A.2). British Columbia (BC) has 100% property tax exemption for eligible devices as well as energy upgrades that result in Gold or Platinum level Leadership in Energy and Environmental Design (LEED) certified buildings [75,76]. In Quebec (QC), RénoVert tax creditis are provided for the energy renovation of residential buildings [77]. Among various FIs, tax incentives have been found to be most effective from environmental and economic point of views [23]. Hence, there is a need to increase the number of tax incentives available for GBs in Canada.

Grant incentives: Grants are another way to offset green residential building costs [78]. They are used as an incentive for the adoption of GBs at an individual as well as community level [17]. Grants are applied to a certain percentage of per capita costs or investment costs of a component. Since a specific economic benefit is associated with GB financial grants, they have proven to be quite successful. Due to a large amount of capital needed for grant incentives, they are mostly suitable as a part of regulatory incentives at provincial or national level [79].

In contrast to the financial tax incentives offered for green construction, numerous grants are available at both provincial and municipality levels in Canada. A list of GB grants present in Canada is provided in Appendix A.3. It is observed that similar to loan incentives, grants are offered for new construction, energy renovation, and specific systems upgradation. The majority of the grants are provided through utility companies in different provinces. The largest number of grants are available in QC through utility provider "Énergir" [80] for both residential and commercial buildings. Some special grants such as Home Energy Low-Income (HELP) [81] are specifically designed for building users with low income [80].

This implies that extensive subsidies are available in Canada. However, Canadian tax incentives are still lacking both in terms of the number and the spectrum covered compared to other countries. Grants are another attractive monetary incentive but are predominantly offered in QC. More of these are required for low-income population in other provinces.

3.1.2. Rebates

Rebates are financial gains that are received by building owners or developers [3], usually when the energy improvement is implemented in the building. Globally, the deployment of rebates has been successful in achieving high energy savings [82]. In Canada, rebates offered by utility programs exceed available loan and grant incentives for buildings. A list of rebates present in Canada is provided in Appendix A.4.

Energy saving potential through upgrades is high for commercial buildings, but this is accompanied by larger initial investment requirements. To counter these costs, rebate amounts up to CA$ 500,000 are provided by the government of Nova Scotia (NS), while most other provinces are offering much lower rebates (up to CA$ 50,000). In the commercial sector, the highest number of rebates are being offered to the residents of BC through FortisBC [83]. In residential sector, rebates offered by municipalities are common for AB while utilities offer rebates are more common in BC, QC, ON and Newfoundland and Labrador. Provincial rebates are offered for residents of NS, Prince Edward Island (PEI), and Yukon. Provincial rebate program in Alberta (AB) offers solar rebates up to CA$ 10,000 for residential buildings, and up to CA$ 500, 000 for commercial and non-profit organizations [84].

Overall, AB and BC provinces are highly committed to developing green residential and commercial buildings through rebates with the aim of creating a sustainable future for their residents.

3.1.3. Dis-incentives

Dis-incentives are financial instruments that work as negative reinforcement towards energy efficiency improvements. Carbon taxation is one of the most common dis-incentives and has been found to be successful in mitigating carbon emission [61]. The tax follows the rationale that the polluter pays for the negative impacts of his energy use in the form of a penalty if the emission rate exceeds a specific limit [85,86]. Carbon taxes have been employed in a number of countries that include the Netherlands, Sweden, Norway, and others [87]. These are determined to be cost-effective instruments that utilize minimum resources [88]. Similarly, researchers have proposed that the introduction of this tax would result in a reduction of GHG emissions as consumers turn towards alternative low-emission energy resources [89,90].

BC has a carbon tax on the use of natural fossil fuels in order to discourage the use of these resources. Carbon tax in BC is applied based on the taxable fuel consumption of a household that relates to cooking, heating as well as transportation. The prices are applicable to gasoline, diesel, propane, coal and natural gas [91]. Carbon-tax was introduced in BC in 2008 and studies have deemed it successful in reducing GHG emissions by 19% with no economic losses [92]. Similarly, a recent study determined the impact of BC's carbon tax in reducing the natural gas use by 7% in the residential sector [93]. AB and QC have similar carbon pricing systems. Recently, a nationwide tax system has been introduced in Canada which is applicable to provinces where the carbon pricing and/or carbon tax systems are still absent under the "Greenhouse Gas Pollution Pricing Act" [94]. The proposed carbon tax by the federal government is currently offered at CA$45/ton and will be increased at the rate of CA$10/ton per year until the year 2022 [95] (Appendix A.15).

With regards to disincentives, the carbon tax has proven successful for Canada unlike other countries of the world. Hence, the proven environmental and economic benefits of carbon tax in BC show the possibilities of coupling the carbon tax with other policy instruments to promote emerging low-carbon technologies such as carbon capture systems for buildings.

3.2. Targeted incentives

Targeted incentives are needed to address the energy improvement needs of specific stakeholders and/or buildings that are vulnerable to high costs risks [96,97]. Hoicka et al. [18] suggested that sub-sets of population should be targeted through incentives to achieve desired outcomes. Table 4 shows the distribution of some important targeted incentives in different provinces of Canada.

3.2.1. Low-income population

Lack of affordable housing is a recognized problem in major cities of Canada. The low-income population is especially vulnerable and needs financial aid to improve the energy performance of their houses and reduce their energy bills. Studies have shown the willingness to participate in an energy efficiency program is especially minimal for low-income families dwelling in older residences [98]. Programs are available in different provinces that specifically target low-income populations for different types of houses (Appendix A.10). These incentives are being offered by both utilities and provincial governments [67,81, 84,99–104]. Some of the incentive programs cover total costs of specific energy improvements [67,81,104], while others offer increased incentives such as those offered by Énergir and Gazifère utilities in QC [102,103]. In fact, in QC the rebates for low-income residents are double the amount of those offered for a normal housing energy upgrade. Manitoba Hydro offers free small scale energy upgrades for such buildings [105].

This implies low-income incentives are present in most provinces but the amount and type of incentive being offered varies. Recent studies on COVID-19 indicate an expected increase in energy poverty as the impacts of lockdown and related economic losses become more evident [106,107]. Hence, more specialized incentives for low-income population will be required to face economic impacts of the current pandemic.

3.2.2. Buildings built during a specific time period

The majority of Canadian buildings were constructed prior to the implementation of new energy-efficient building codes. Furthermore, old buildings that form a part of the cultural heritage have limited options in energy upgrades and require special incentives for energy improvement [97,108]. Hence it is essential to reduce the energy use in these old buildings to meet carbon targets. Home Weatherization program in Ontario (ON) [109] (for buildings constructed before 1975) and Power Smart Home Insulation Program in MB [105] (for buildings built prior to 1999) are good examples of FIs targeting buildings built under older building codes (Appendix A.11).

Though a number of rebates and subsidies are available for retrofitting existing buildings, only ON and MB provinces seem to target buildings belonging to a specific time period. Such incentives are required to ensure that buildings retrofits that yield maximum benefits are prioritized.

3.2.3. Non-profit organizations

Non-profit organizations (NPOs) can help increase energy efficiency by providing awareness and help to the marginalized communities. The buildings directly under NPOs usually have high operational costs and FIs can help in reducing these costs. Energy efficiency requirements

Table 4
Summary of targeted financial incentives in Canada.

Province	Residential					Commercial				
	Low-income	Heritage buildings	Non-profit	Aboriginals	Landlord and tenants	Low-income	Heritage buildings	Non-profit	Aboriginals	Landlord and tenants
Alberta	✓		✓			✓		✓		
British Columbia	✓		✓	✓		✓		✓	✓	
Manitoba	✓	✓		✓	✓				✓	
New Brunswick	✓		✓							
Newfoundland and Labrador	✓									
Nova Scotia								✓		
Nunavut										
Ontario	✓	✓		✓				✓		
Prince Edward Island	✓									
Quebec	✓				✓	✓		✓		
Saskatchewan										
Yukon										

depend upon the particular services being performed by the NPO [110]. Type of buildings that can benefit from these FIs are sports and recreation, community centers, health centers, religious, social housing, co-op housing, housing for aboriginals etc. See Appendix A.12 for FIs incentives present for NPOs in Canada. These incentives are usually bundled under the same program that also offers incentives for aboriginal housing [67], low-income housing [102], or residential and commercial buildings [84].

3.2.4. Aboriginal population

Future sustainability of the aboriginal community in Canada faces economic, social and environmental challenges [111]. For this reason, specialized incentives have been provided by different provinces to meet sustainability goals (see Appendix A.13 for details). Overtime, ON has updated its incentives programmes for the aboriginal community starting from the tax exemption and moving towards differentiated Feed-in Tariffs and specialized contract and tendering schemes with local ownership criteria [112]. In addition, free upgrades are also offered to aboriginal communities in ON under First Nations Conservation Program [113]. Manitoba Hydro offers "Pay As You Save (PAYS) Financing" to aboriginal population to improve energy efficiciny through installation of geothermal systems [114]. Similarly, BC is offering incentives for residential and commercial buildings belonging to aboriginal community [83].

Aboriginal people are one of the most marginalized communities in Canada with limited energy resources. Only BC, ON and MB are currently offering incentives for aboriginals. Similar to the scenario with low-income populations, more incentives are required to be deployed for aboriginals at provincial and municipal levels as the current COVID-19 pandemic unevenly impacts the vulnerable populations in Canada.

3.2.5. Landlords and tenants

Extensive research has shown that the cost of investment for energy upgrades and limited return on investment are major barriers in energy efficiency improvement of rental housing sector [115–117]. In rental buildings, benefits and costs associated with energy efficient upgrades are not equally shared by the owners and the tenants. In most cases, the benefits of lower energy bills and comfort are reaped by the tenants while the owners have to make capital investments for the energy efficiency improvements [118–121]. This principal agent problem results in a low willingness to invest in energy upgrades even when FIs are available. This is illustrated by Phillips [122] study that showed uptake of grants for insulation was much higher for owner-occupied buildings compared to rented buildings. Therefore, special incentives are needed to ensure the benefits and costs are obtained by both landlords and tenants. In order to improve the energy efficiency of rental housing sector, utility providers in two provinces, MB and QC, offer incentives specifically designed for landlords and tenants (Appendix A.14).

Hence, only a limited FIs are available specifically for landlord and tenants in Canada. In addition, studies indicate rental occupancy is increasing in major cities such as Toronto (ON) and Vancouver (BC) where more than 40% of citys' GHG emissions are related to high-rise apartments [123]. Therefore, more incentives need to be introduced for rental building stakeholders.

3.2.6. Buildings built to specific building standard/code

Provision of green certification to a building adds additional burdens to the costs of GBs [124]. Hence, some FIs in Canada are specifically designed for the rating system and certification of GB. CMHC and NS government provides incentives for houses built to Energy Star or R-2000 Standards [64,125]. Similarly, incentives for EnerGuide homes are offered by utility providers in BC and governments of NS and PEI [81,104,125]. Government of PEI also offers incentives for new construction with energy performance either 20% better than Energy Star Homes or 50% better than R-2000 [81]. Two municipalities in AB: Edmonton and City of Medicine Hat offer rebates when existing houses are evaluated and improved [126,127]. In addition, building energy codes are being revised and upgraded in Canada at national and provincial levels, such as BC energy step code for new buildings [31]. Fig. 4 shows the incentives currently being offered by FortisBC [128] for new residential buildings in BC.

At present, FIs offered in PEI and NS are most adaptable by builders and developers as they are offered over a wider range of energy standards and ratings. Similar, efforts are required from other provinces for faster transition to a more energy efficient building stock.

4. Financial incentives in Canada regulatory regimes

Canada's climate and energy policies are interrelated and form a

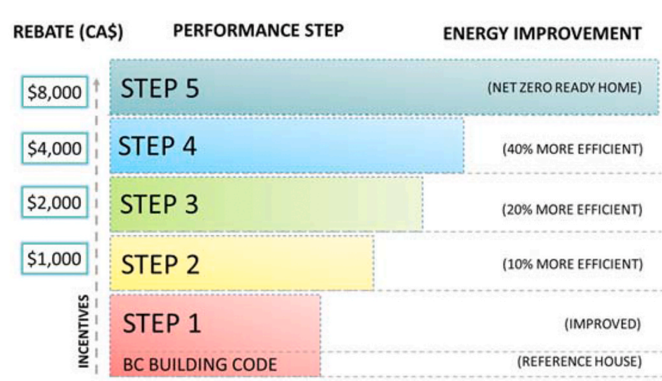

Fig. 4. FortisBC rebates at different performance levels of BC Energy Step Code [31,128].

crucial part of FIs deployed for the buildings [129]. Politically, the governance of Canada is distributed into two main levels: (1) federal and (2) provincial and municipal territories. The federal government is mainly responsible for developing national energy policies in line with international agreements and deploying the necessary resources such as provincial-level grants to assist the accomplishment of climate targets. Building standards, as well as assessment criteria, also form a part of the federal government responsibilities [130]. In addition, under the Canadian Environmental Protection Act of 1999, the federal government can place limits on carbon emissions such as through the application of carbon tax on provinces. The provincial governments are responsible for the resources and can follow the standards set by the federal government. There is a wide variation of economic and environmental conditions among different provinces that change the demand for energy. Similarly, socio-economic conditions vary and change at urban and rural scales with development [35]; hence, the types of energy upgrades and FIs will vary according to a buildings' location and time of FIs application. Energy decisions performed at provincial levels are used as the basis of FIs offered at the municipality level. Though energy and emission related decisions are performed at all three government levels, the decisions do not always follow from federal to municipal level [130].

4.1. Federal

At the Federal level, most FIs offered for green residential buildings are in the form of loans offered by the financial institutions [80]. The number of incentives offered depends upon the life stage (i.e. design, construction, operation, demolition) of a building and the type of GB certification. For example, CMHC offers refunds on financial loans up to 15% for an Energy Star rated house and up to 25% for an R-2000 certified building [64]. Different banking organizations in Canada are also offering incentives for homeowners who want to construct or upgrade a house to GB standards. Banks are providing incentives especially for the installation of solar panels and high energy efficiency equipment [65]. Canadian Green Building Council also offers registration and certification fees waivers for buildings complying to LEED® Canada under Homes Affordable Housing Program [131]. Genworth Financial Canada incentive program for green homes provides a premium refund for energy efficient homes [80]. Overall, several FIs are offered at Federal level. However, it should be noted that federal incentives cannot be equally availed at all locations in Canada because of differences in demographics, weather, types of constructions, local resources, technologies and components along with certification methods in different regions.

4.2. Provincial

Provincial incentives commonly offered through the provincial governments or the utilities are useful in the promotion of GBs. Table 5 provides an overview of FIs available in different provinces of Canada with details in Appendix A.5. It is seen that a large portion of FIs are offered by utility companies mostly in the form of rebates on individual energy upgrades. Compared to other provinces, AB, NS and PEI governments offer the largest FIs [81,84,125]. AB, however, does not have any FIs from utility providers. In some provinces, organizations play an important part in energy performance improvement of building. For example, the Northwest Territories are dependent on incentives provided by Arctic Energy Alliance [132] and do not have FIs from the provincial government, local municipalities, and utilities. At provincial level, BC, MB and SK have a wider variety of FIs.

4.3. Municipal

FIs utilized at the municipal level particularly target energy efficiency of housing stocks [133]. Municipal FI models are based on local conditions, and hence are most effective in the generation of GB neighborhoods. Since municipal GB incentives have significant variations regarding end goals, some municipalities are becoming much more efficient with regard to their energy and water use. For instance, the District of Saanich in BC has one of the most elaborate incentive schemes for green residential buildings and offers rebates for houses designed to any four of the energy standards: EnerGuide 80, R-2000, Built Green or Power Smart for New Homes [134]. This increased scope and flexibility has enabled the city to improve its residential buildings. In the same vein, Markham, Calgary, and Vancouver are good examples of Canadian cities that have made significant progress in increasing their green building stocks [134]. For commercial buildings in Toronto, two programs, a loan and an Eco-Roof incentive program, specifically target construction of green and/or cool roofs [71,135]. Programs such Eco-roof incentive encourage reduction of a building as well as managing storm water [136]. Hence, similar incentives that can yield multiple benefits need to be encouraged at municipal level.

5. Effectiveness of financial incentives

The evaluation of FIs in the Canadian context can be examined by a comprehensive review of research performed in Canada and other countries of the world. Research review revealed four major classifications of FIs' effectiveness evaluation (Fig. 5.) that are explained in the following sub-sections.

5.1. Time of evaluation

The time of evaluation of FIs divides the analysis methods into either ex-post or ex-ante analysis. The ex-post analysis evaluates the effect of energy efficiency interventions over time and provides empirical results. Ex-ante analysis forecasts the impacts of incentives before they are implemented and give expected results [137,138].

Table 5
Summary of provincial level financial incentives in Canada.

Province	Residential				Commercial			
	Tax	Loans	Grants	Rebates	Tax	Loans	Grants	Rebates
Alberta		✓		✓				✓
British Columbia		✓	✓	✓				✓
Manitoba		✓		✓		✓		✓
New Brunswick		✓						
Newfoundland and Labrador		✓		✓				✓
Nova Scotia		✓		✓				✓
Nunavut		✓		✓				✓
Ontario	✓	✓		✓		✓		✓
Prince Edward Island		✓	✓					
Quebec	✓	✓					✓	
Saskatchewan		✓	✓	✓			✓	✓
Yukon		✓		✓				✓

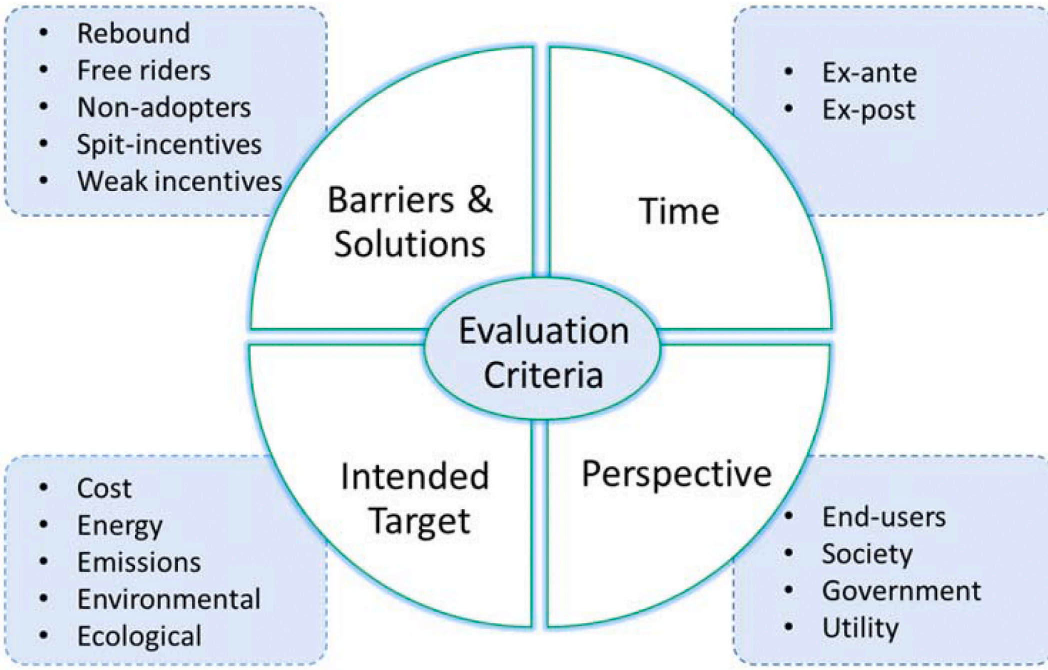

Fig. 5. Important criteria considered for literature review on effectiveness evaluation.

Ex-ante analysis for FIs related to energy efficiency is usually based on engineering economics. Some researchers have shown that the results from ex-ante analysis tend to be over-optimistic compared to more realistic results from ex-post analysis [23,139,140]. In contrast, Lang and Siler [141] did not find overoptimistic results from ex-ante analysis. Over time the researchers' focus has shifted from ex-ante towards ex-post analysis, possibly due to accountability of institutional behavior and accurate results of ex-post analysis [142]. However, the ex-ante analysis can help reduce risks related to the resources used to implement FIs, provided suitable assumptions are made for analysis. Details of some of the most common methods are provided in Table 6.

Ex-post analysis can be conducted through five major methods [11]: a top-down approach, bottom-up approach, an amalgamation of top-down and bottom-up approaches, econometric modelling and policy theory. Among these methods, econometric modelling has been most extensively applied and used to study the diffusion of energy conservation technologies, free-riding effect and comparing FIs [143–148]. However, econometric modelling methods are expensive to implement and need specific data. Other ex-post analysis methods include use of Panel Data Models [149], Data Envelope Analysis [150], Life Cycle Assessment (LCA) [151] and Grey Model (GM) [152].

Ex-ante analysis can be conducted through two major methods: forecasting and backcasting. Forecasting methods are based on bottom-up energy-economy models and are more common in effectiveness evaluation studies. Energy-economy models can be categorized in four types: simulation, optimization, accounting, and hybrid models [153]. The majority of these models are being used to determine the impact of policy instruments on building energy cost, use and emissions [153–157]. The backcasting method, as opposed to the forecasting method, is capable of determining the path needed to achieve the desired target [158,159].

Hence, both ex-post and ex-ante methods have their strengths and weaknesses, and lessons learned from these methods can help in obtaining FIs with desired effectiveness.

5.2. Stakeholders' perspectives

The optimal energy performance of a building will vary from different stakeholder's perspectives [160]; hence, the evaluation of FIs from different perspectives will provide different results. Stakeholders for an energy efficiency program include program administrator (e.g. utility), government, society or the end-users. It is quite possible that an incentive has high effectiveness from an end-user's point of view but has a low effectiveness from the society's or program administrator's perspective. Researchers have evaluated effectiveness from the end-users, society and government perspectives [10,11,144,145,148,165–169]; technical, program administrator and multiple stakeholders perspectives [8,45,170–175]; and micro-economic (end-users) and macro-economic (societal) perspectives [176,177].

5.3. Intended target

Effectiveness of a FI can be defined as the degree to which it contributes to the achievement of the intended target of FI [178]. The effectiveness value can help decision-makers in providing justification for the continuation of investment in GB incentives by the stakeholders [3]. Depending on the intended goal of the FIs, studies on the effectiveness of FIs of GBs can be broadly categorized into two groups: environmental effectiveness and cost-effectiveness. Key literature performed related to FIs for residential and commercial buildings is provided in Appendix B.1. Some common models used by different researchers to evaluate FI effectiveness are provided in Table 7.

Environmental effectiveness can be defined in same manner Jurušs and Brizga [190] defined tax incentives effectiveness i.e. the degree of achievement in terms of pollution mitigation targets, technical innovation or substitution of existing products with a more environmentally friendly product. Environmental effectiveness is an important parameter that can also help assess the rebound effect due to incentives [191].

Cost-effectiveness is a common parameter used in engineering economic evaluations of FIs. Harmelink et al. [11] defined cost-effectiveness as the result of application of a policy instrument to the finances needed to achieve the desired target. Cost-effectiveness results impact energy policy, program design and budget allocation [170]. The success of FI on energy efficient appliances depends upon the specific conditions under which the cost-effectiveness is being determined. Table 8 provides an overview of different parameters that need

Table 6
Ex-ante and ex-post methods for financial incentives effectiveness.

Evaluation	Approach	Method	Advantage	Drawbacks	Ref.
Ex-post	Top-down approach	Aggregation of different indicators in achieving target is made by assuming that the amount of energy efficiency is constant over period of evaluation. The amount of energy used with application of instruments is compared with energy efficiency baseline and gives the energy saved	Less time consuming	Not possible to assess impact of individual instruments	[11,161]
	Bottom-up Approach	Effects of individual instruments are assessed to determine the impact on energy target achievement	Easy to identify the performance of individual instrument in kWh, GJ etc.	Difficult evaluation in case of instruments assigned in packages	[11,161]
	Combination of Top-down and Bottom-up Approach	Two methods (Top-down and Bottom-up Approach) are combined to assess the impact on energy targets	Weaknesses of top-down and bottom approach methods are covered.		[11,162]
	Econometric Modelling	Based on statistical analysis of factors that can potentially affect the instrument evaluation. Panel Data Model, diffusion model are examples of econometric models commonly used in effectiveness studies	Useful for evaluation of taxes	Does not indicate the cause of poor performance of instrument	[11,108, 146,147, 163]
	Policy Theory	Complementary method to top-down, bottom up and econometric modelling with particular emphasis on bottom up approaches Policy Theory is also called Logic Model Analysis, Intervention Theory, Theory-Based Approach, Realistic Evaluation Theory or Program Theory	A comprehensive evaluation of the whole policy implementation process. Easy to identify factors impacting success or failure of incentive.		[11,164]
Ex-ante	Forecasting (Energy Economy Models)	Energy-economy models are developed based on robust economic and engineering principles and determine impacts of FIs on the energy savings or reduction in carbon emissions. Four main methods are used for generating these models: (1) (Market) Simulation (2) Optimization (3) Accounting (4) Hybrid Models Several models are developed and extensively used depending upon the evaluation goal. Examples of some of these methods are: Canadian Integrated Modelling System (CIMS) National Energy Modeling System (NEMS) Long-range Energy Alternatives Planning (LEAP) MARKet Allocation (MARKAL)	Capable of identifying best combination of energy efficiency improvements needed under cost and time constraints CIMS hybrid energy-economy model capable of determining interaction between energy supply and macroeconomic performance NEMS model provides long term projections of energy technologies based on operating and investment costs LEAP is capable of analyzing both economic and environmental impacts MARKAL is a bottom up energy based model can determine evolution of end-use energy systems	Can be restricted to a specific region and sector CIM model is specifically designed for assessing impacts in Canada and is focused on energy users and energy supply and industries. NEMS is focused on US domestic sector MARKAL is focused for EU energy systems	[153–157]
	Backcasting Analysis	A future can be achieved by exploring scenarios that give desired target	The process involves methodological steps that have sequenced order that varies with specific backcasting approach	Conventional backcasting method is applicable to long term analysis only	[158,159]

to be considered for evaluating cost-effectiveness from different perspectives.

Cost-effectiveness from end-user perspectives is concerned with the direct benefits and investments related to energy saving measures [11]. Some studies on end-users cost-effectiveness have also included the change in building sales value or rentability in the evaluation [184, 192–194]. Some studies found that from an end-users' perspective, subsidies and taxes are highly cost-effective while costs on emissions are not; however, from societal perspective costs on emission (carbon taxes) have high cost-effectiveness while tax credits and subsidies have low effectiveness [23,176].

Limited studied have measured both environmental effectiveness and cost-effectiveness of FIs. Most studies either focused on a single energy upgrade (example: natural gas furnace, electric appliances); a single incentive (example: rebate, tax); or single stakeholder perspective such as end-users perspective [191,195]. The most comprehensive study on multiple targets was performed by Ürge-Vorsatz et al. [23]. The review study compared 20 policy instruments that had been evaluated in 60 different ex-post evaluation studies. In order to enable ease in comparison, three qualitative scales (High, medium and low) were applied for cost- and environmental effectiveness [23] (Fig. 6). Appraisal results on societal level showed that carbon tax had low environmental and cost-effectiveness; capital subsidies, grants, and soft-loans had high environmental-effectiveness but low cost-effectiveness; whereas, tax-exemptions had both high environmental and cost-effectiveness among the FIs [23]. Similar comparison plots are needed for end-users and government perspectives.

5.4. Barriers to the success of financial incentives

Despite the proven advantages of FIs [8,163] a number of barriers are present that reduce effectiveness. Table 9 gives description of some major barriers affecting effectiveness.

5.4.1. Split incentives

Split incentives are a common barrier that results in ineffectiveness of FIs in the rented residential and commercial buildings [118,119,198]. This barrier occurs when the benefits and costs are not equally

Table 7
Effectiveness evaluation models for financial incentives.

Effectiveness type	Model	Ref.
Environmental	Specific environmental target in comparison with that achieved by an alternative FI	[147,179–181]
Emission reduction	Reduction in CO_2 emission (tCO_2)	[8,147,168,178,182]
Energy	$E_{Eff} = 100X\frac{(PE_{ex-ante} - PE_{ex-post})}{PE_{ex-ante}} = \frac{\Delta PE}{PE_{ex-ante}}$ (%) where: E_{Eff} = Energy effectiveness PE= Primary Energy Demand	[183]
Eco-logical cost	$ECE = \frac{C_f}{V_E}$ where: ECE = Eco-logical cost effectiveness C_f = financial costs of energy upgrade (Cost/m^2) VE = reduction in environmental impact due to energy upgrade (Pt/m^2) Pt = LCA eco-indicator point	[184]
Cost	$C_{Eff} = \frac{\textit{program effects in physical terms}}{\textit{costs (e.g. CAD\$)}}$ where: C_{Eff} = Cost-Effectiveness	[185]
	%-age reduction in *PBP* where: *PBP*= Payback Period	[186–189]
	Benefit-to-cost Ratio (*B/C*)	[23,170,172]

Table 8
Cost-effectiveness for different perspectives.

Parameter	End users perspective	Society perspective	Government perspective	Ref.
Costs	Additional costs to be paid by people responsible for energy saving measure implementation compared to reference case	- Costs to be incurred by society compared to reference case. - Societal cost-effectiveness	Amount spend by government in form of both financial and non-financial incentives provided to end-users	[11, 170]
Time	Actual costs at time of payments	Longer time frame with discounted costs evaluation	Longer time frame with discounted costs evaluation	[11]
Indicators	- Simple *PBP* - Investment profit - Marginal costs - Cost of saved energy - Benefit-to-cost Ratio (*B/C*) - Change in LCC	- Total costs per unit of energy saved Program costs per unit of energy saved - FI per unit of energy saved - Fiscal environment - Non-energy impacts (e.g. health and welfare)	- Total costs per unit of energy saved Program costs per unit of energy saved - FI per unit of energy saved	[170]
Subsides	✓	✖		[23, 176]
Taxes	✓	✖		
Cost emissions	✖	✓		
Interest rate	Real interest rate	Societal interest rate		

distributed among stakeholders resulting in unwillingness to invest in expensive technological options [41,119,198,207]. Split incentives can lead to underinvestment in the energy efficiency programs offered by utilities and government [119,198] or a performance gap between the energy model and the actual building energy use in non-domestic buildings [196]. Several studies empirically provided evidence to the scale of this issue [118,119,198]. Charlier [119] suggested the introduction of Energy Performance Contracts (EPCs) as solution to counter this problem. As urbanization in major cities continues to increase and trends of high-rise apartment and buildings continue in Canada [123], special efforts are needed for removing split-incentives from buildings.

5.4.2. Weak incentives

Weak incentives are another common problem that result in low cost and/or environmental effectiveness. Weak incentives discourage the investors to make energy efficient choices even if the investment is cost-effective over time for the end users or society [9,108]. The unclear benefits associated with weak FIs and consumers preference for immediate savings lead to low confidence in making an energy efficient choices [9,208,209]. Weak FIs can also occur due to low incentive amount than needed to achieve the desired target [82,108,210].

5.4.3. Time of implementation

Provision of FI at a suitable time is important to achieve full sustainability targets. For instance, incentives such as investment tax credits are attractive for building users; however, when applied during the buildings' operation period, the replacement of building equipment (old appliances, furnaces or/and HVAC systems) may occur prior to the end of useful life. This will offset the maximum possible sustainability targets. On the other hand, the application of utility rebate incentives during a buildings' operation time will encourage the use of equipment to their full useful life and meet sustainable goals of equipment energy upgrade [200]. Sometimes an existing FI such as retrofitting incentives may become unattractive to a user due to reduced utility prices. In the same vein, studies have shown that sometimes incentives for demolition and reconstruction can be more useful than renovation subsidies [108]. Hence, more effective FI models need to be developed and optimized by taking into account the different phases of building life and external factors affecting the building use [200]. Similarly, the local socio-economic conditions will affect the type of FIs that needs to be

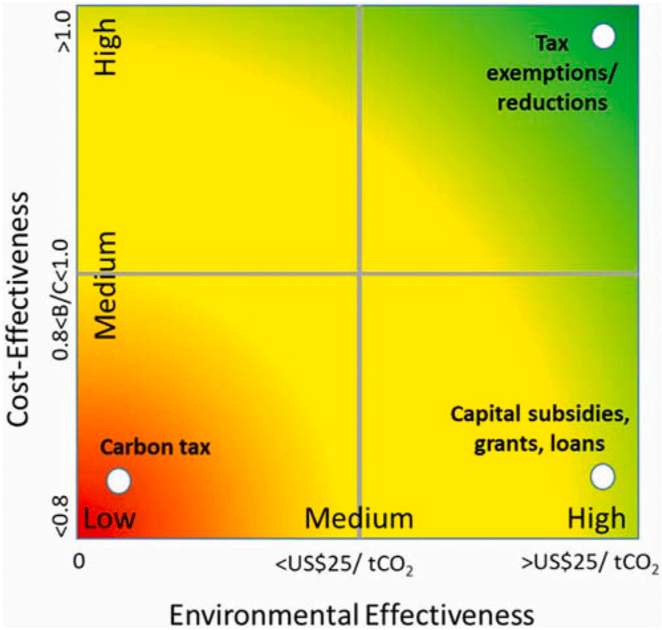

Fig. 6. Environmental effectiveness vs cost-effectiveness from a societal perspective (adapted from Ürge-Vorsatz et al. [23]).

deployed. For example, currently (under COVID-19 situation) retrofit of buildings is being seen as a solution to economy revival and sustainability [12] therefore more FIs related to building retrofits will be needed.

5.4.4. *Negative interaction between FIs*

A number of FIs and policy instruments are present for energy savings in buildings and it is important to understand how they will interact with each other and impact their effectiveness. Interaction effects are influenced by the policy instrument steering mechanism, scope and timing of implementation [201,211]. This interaction can result in either positive, neutral or negative impact on effectiveness [201,211]. For example, Boonekamp [202] showed negative interaction between energy taxes, subsidies and regulations in Netherlands that resulted in 13–30% less effectiveness compared to some of sum of effectiveness for individual instruments. Table 10 shows interaction between different policy instruments from a study in Europe [204]. Despite the importance of interaction between FIs and other instruments there are scant studies addressing the problem [201–204]. More studies are needed on interaction especially in the Canadian context.

5.4.5. *Behavioral impacts*

Behavioral impacts are often complex and constrained by type of adopter (free riders, switchers and non-takers) along with social, economic, and physical parameters [212]. Free riders and rebound effect are most common behavioral impacts [145,148,169,175,181,191,213,

Table 9
Barriers to the success of different financial incentives.

Barrier/Anti-incentive	Description	Ref.
Split incentives	Particularly important in rental housings where interests of two parties conflict and neither the landlord (due to low ROI) nor the tenant (high initial costs) wants to invest in energy efficiency upgrade	[119,196–198]
Weak incentives	Lack of attractive amount of incentive and connection between the government budget and the energy target needed to be achieved by FIs	[9,11,197,199]
Time of implementation	Application of FIs at wrong time	[200]
Negative impacts of FIs interaction	Mitigating impacts are negative interaction between two policy instruments that result in reduced savings	[201–204]
Behavioral impacts	- Low priority towards energy efficiency (Low resource consumption culture present in most developed countries makes it difficult for FIs to be successful) - Free riders (Free-riders are consumers who would have performed energy upgrade regardless of introduction of FIs.) - Non-takers (Non-takers are consumers who do not perform energy upgrade even with the introduction of FIs) - Rebound effect (Rebound effect results in less energy savings compared to expected due to introduction of FIs and is a source of energy efficiency gap)	[11,21,145,148,163,169,175,191,199]
Other Barriers	- Tax exemptions - High initial investment - Long payback periods - Transaction costs - Limited incentives for large buildings - Lack of information (Awareness of targeted end-users about the process of acquiring FIs) - Lack of technical expertise	[9,11,21,191,197,199,205,206]

Table 10
Interaction matrix between financial and non-financial policy instruments.

	Financial Incentives					Other Policy Instruments		
	Tax rebates	Low-interest Loans	Grants	On-Bill Finance	Carbon Tax	Building Standard	Eco-Labelling	Regulations
Tax rebates		✖	✖	*	✓	✓	✓	o
Low-interest Loans			✖	✖	✓	✓	✓	o
Grants				✖	✓	✓	✓	o
On-Bill Finance					✓	✓	✓	o
Carbon Tax						✓	✓	✓
Building Standard							✓	o
Eco-Labelling								o
Regulations								

Note- (✓): positive interaction; (**o**): nuetral interaction; - (✖): negative interaction; (*): information not present.
Source (adapted from Rosenow et al. [204]):

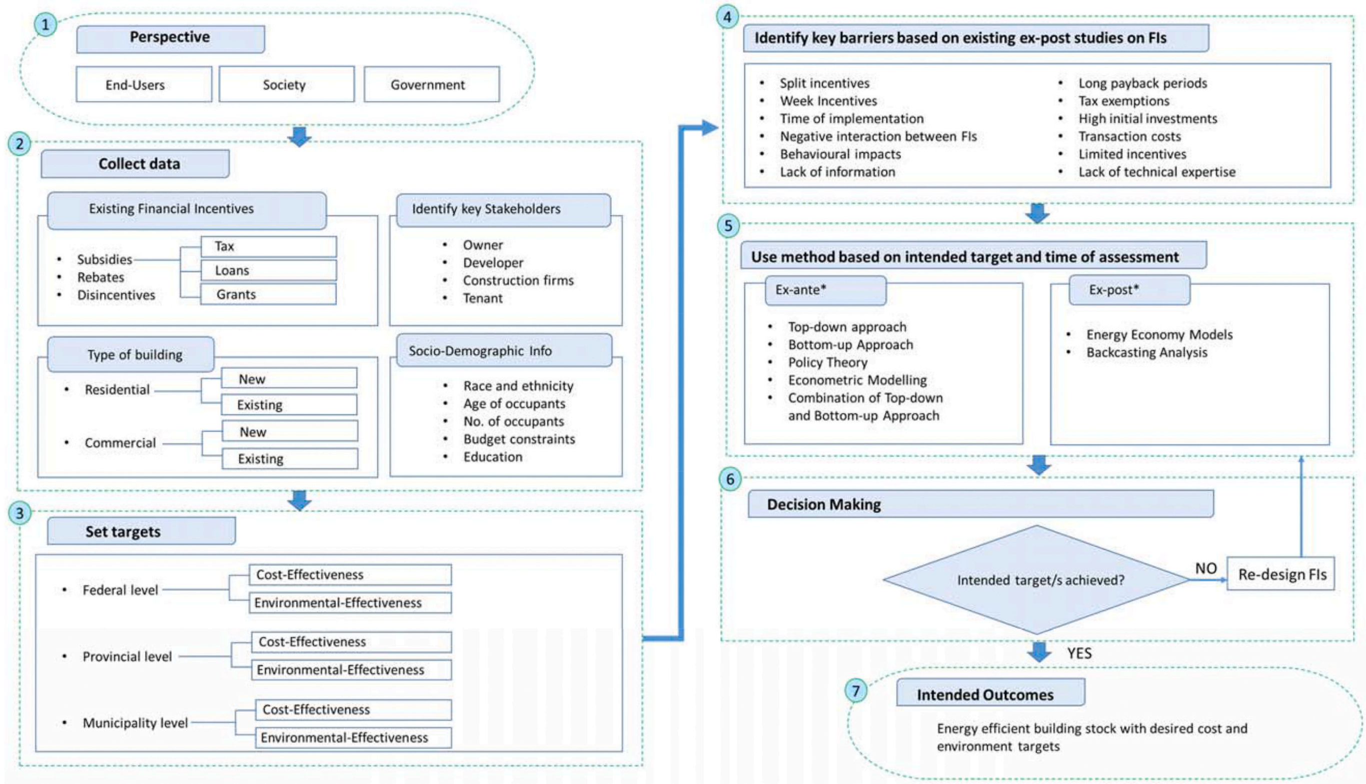

Fig. 7. Approach for evaluating the effectiveness of financial incentives.
(*These are all the most commonly used ex-post and ex-ante methods. The researchers will need to select only one method according to perspective and target under consideration.)

214]. Researchers have also shown that free-ridership problem is more for energy measures that are replaced more frequently; hence, boiler incentive will have higher number of free riders compared to FIs for insulation [21]. The energy use behavior and preferences of stakeholders also impact the effectiveness of FIs [98]. For example, a low priority may be given to energy efficiency when energy is low priced, resulting in a lower effectiveness of FIs [191,199]. Similarly, some adopters may prefer tax credit over interest-free loans [98]. In addition to these occupant behavior is important in assessing the realistic energy savings due to energy upgrade [215,216]. For instance, Rana et al. [217] showed that energy, emission, and cost savings vary for same energy upgrades with different occupancy profiles. Hence, occupant behavior may result in either an increase or a decrease in FIs' effectiveness.

5.4.6. *Other barriers*

In addition to above, researchers have also identified other barriers impacting effectiveness. These include: provision of tax exemptions [197], high initial investments [191], long payback periods [199], transaction costs (indirect costs) [218], limited incentives for large buildings [45], lack of information [9,11,191,205] and technical expertise [205,206].

5.5. *Recommended approach for the implementation of financial incentives*

Based on the literature review, a seven-step research approach (Fig. 7) is proposed to obtain the desired effectiveness of FIs in residential and commercial buildings. The approach is described below:

1) Major stakeholders' perspectives need to be considered in order to minimize the associated risks. For instance, end-users in North America are more transient than other countries of the world; an average home-owner changes home every eight years [219]. Thus, it is essential that strong incentives are present, which are effective in achieving energy and carbon mitigating targets for associated stakeholders.
2) Collection of data related to the buildings that includes existing incentives, occupancy profiles, socio-demographic conditions, and stakeholders: This information is needed to make informed decisions, such as assessing a need of targeted incentives for marginalized populations or for historical buildings in a municipality.
3) The regulatory level is important to assess the degree of influence of deployed FIs as well as the available resources. For example, at municipal scale the degree of influence is high but a limited set of resources are present to achieve the desired targets.
4) Identification of key barriers that may influence effectiveness is essential to assure minimum wastage of resources: For instance, ignoring the interaction impact of other policy instruments can decrease the effectiveness.
5) The method used for assessing effectiveness depends on stage of FIs program: For new FIs (example for a new technology), ex-ante method is the only option for analysis. However, if incentives are under revision stage ex-post is preferred option as it provides more realistic empirical results. When possible both methods should be used to ensure the FIs are as effective as desired.
6) If the effectiveness value obtained from ex-ante or ex-post methods is below the desired level, there is a need for FIs to be re-designed and re-evaluated.
7) When effectiveness value meets the set target, an energy efficient building stock can be obtained.

FIs effectiveness has become even more important with COVID-19. The global pandemic has negatively impacted not only health sector but also climate change policies as most resources were redirected in providing urgent relief to the citizens [220]. Furthermore, there are fears of a rebound to fossil fuels as countries try to make quick economic recovery [12]; hence, urgent actions are required to prevent this rebound. As more pandemics are predicted to occur in future [221], it is necessary that long-term recovery strategies are designed keeping climate change in mind. In fact, making existing buildings greener through energy retrofits is seen as one of the most viable solutions to ensure both economic recovery and climate change mitigation [12]. With the anticipated economic and resources constraints, FIs will be highly useful instrument for making energy efficient buildings in the coming years.

6. Conclusion and recommendations

6.1. Conclusions

A detailed literature review was performed to identify the types and quantities of FIs present for promoting GBs in Canada. This work revealed major regional variations in the FIs available for residential and commercial buildings. Loans supplied by financial institutions and rebates by utilities are the most common FIs in all provinces of Canada. Three provinces (ON, QC and BC) are leading the way in the availability and promotion of FIs for GBs construction in Canada. These provinces have FIs that ensure the penetration of energy efficient technologies and are hence paving the path towards deployment of more stringent building energy standards. Despite the presence of a number of FIs, more targeted FIs are required for low-income housing, aboriginal communities, non-profit organizations, rental housing stakeholders and heritage buildings.

In addition, published literature on FIs effectiveness also revealed that a number of factors impact the evaluation results. These factors can be grouped into four criteria: stakeholder perspective (end-users, government, society, etc.), time of evaluation (ex-ante and ex-post), type of incentive (subsidy, rebate, dis-incentive), and the intended target. There also exists a non-uniformity in the definition of effectiveness, as well as the methods and models used for evaluation. These differences make it difficult to compare evaluation studies and make conclusive decisions. A deeper understanding of the interaction between different policy instruments, investor behavior and preferences of targeted stakeholders is essential to remove barriers and ensure the success of FI. There is also a need for more comparative studies on FIs effectiveness from different perspectives (end-users, society, and government) using ex-ante and ex-post evaluation approaches.

6.2. Policy implications

The policy implications for different stakeholders associated with design, implementation, and use of FIs in GBs are as follows:

- From the government perspective, there is a need to deploy energy incentive policies that encourage high effectiveness from different stakeholders' perspectives.
  - Federal, provincial and municipality governments should encourage incentives for special groups that include aboriginal communities, elderly population, new immigrants, etc.
  - FIs design should follow the building construction trends (e.g. MURBs construction is on the rise in Canada), changes in population demographics (e.g. more retired and elderly population will be living in residential buildings of Canada), changes in energy tariffs and carbon taxes as well as the changes in the costs of different technologies and systems.
  - More FIs are needed for renewable energy resources deployment, buildings with different construction vintage, demolition and renovation stage of buildings.
- From the utility providers' perspective, there is a need to deploy incentives that are in line with the current building energy codes and standards. Special emphasis should be made on the provision of incentives for new technologies and systems that yield maximum environmental benefits.
- From the end-users' perspective, there is a need to increase awareness on the availability of FIs, the process of obtaining FIs, and the associated benefits. In addition, the results from previous incentive programs and pilot studies should be made readily available.

CRediT authorship contribution statement

Anber Rana: Conceptualization, Investigation, Methodology, Writing - original draft. **Rehan Sadiq:** Supervision, Writing - review & editing. **M. Shahria Alam:** Supervision, Writing - review & editing. **Hirushie Karunathilake:** Supervision, Writing - review & editing. **Kasun Hewage:** Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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