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Building retro-commissioning standard and policy: status quo and future directions

Structured abstract

Purpose

This paper aims to review standards on or related to retro-commissioning (RCx) and policy measures that are applicable for fostering wider adoption of RCx in existing buildings. In addition to engendering broader polemic debate to address the respective gap in the prevailing body of green building knowledge, the research outcome signposts future directions of works required for developing the needed standard and policy.

Design/methodology/approach

Following an integrative review approach, RCx-related literature, statutes, publications of public and professional organizations, and standards published by institutions including the International Organization for Standardization and other peer organizations in the United States, the United Kingdom, Canada and Germany were reviewed.

Findings

Cities such as Hong Kong and New York in the world's two largest economies (China and the US) have been proactive in the pursuit of energy-efficient buildings. Various US cities have imposed statutory requirements on RCx. The need of an international standard on RCx and a bespoke policy for driving the uptake of RCx was also identified.

Research limitations/implications

Drawn from the research includes the need of further policy research studies to direct how an appropriate policy could be established to engender wider RCx adoption internationally.

Practical limitations/implications

Practical implications centre on the identified need to develop a specific standard of RCx works. Making such a standard available to facilities management practitioners is pivotal to realizing the goal of green buildings.

Originality/value

This study provides new insights, especially the future directions in developing bespoke RCx standard and policy, for greening the existing buildings.

Paper type

General review

Keywords

Building performance, commissioning, energy, environment, law, policy, standard, retro-commissioning

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Introduction

Facilities in buildings, such as air-conditioning, electrical and lighting installations, are integral to providing a safe, healthy, comfortable and productive environment for their end users (Chartered Institution of Building Services Engineers, 2014; Lai and Man, 2017). These facilities consume substantial amounts of energy, thus contributing to the global climate change (Intergovernmental Panel on Climate Change, 2021). Minimizing building energy use, therefore, is a key task for facilities managers of existing buildings, and it is a prioritised Sustainable Development Goal (SDG) of the United Nations (2022a). Working towards this goal, many policies, standards and rating schemes have been introduced to enhance building environmental performance and promote green buildings (e.g., LEED in the United States (US), BREEAM in the United Kingdom (UK), "Three Star" Building Rating System in China, BEAM Plus in Hong Kong) (Man et al., 2012; Lu and Lai, 2019).

For decades, many cities have been proactive in the pursuit of green buildings; one notable example is Hong Kong - an international city in Asia with a remarkably high density of buildings and population. As a voluntary initiative, the Hong Kong Government issued guidelines to assist building users and managers to improve their awareness of greenhouse gas (GHG) emissions, measure building GHG emission performance and actively participate in actions to combat climate change (Lai et al., 2012). In 2012, the Buildings Energy Efficiency Ordinance was enacted, which imposes mandatory requirements on building energy performance. Recognizing the need to expedite energy reduction, the Government has further promoted the use of retro-commissioning (RCx) to improve the performance of buildings in Hong Kong (Electrical and Mechanical Services Department, 2019).

Different from traditional commissioning (Cx), which mainly checks if the different components of a system are installed, quality-assured and functional as stated in the design intent, RCx is a knowledge-based systematic process to periodically check an existing building's performance. As a crucial part of facilities management (FM), RCx aims at identifying operational improvements for built facilities, thus guaranteeing the facilities are run at the optimum and energy-efficiency condition throughout the operation (Noye et al., 2016).

RCx covers the scope of "existing building commissioning", "re-commissioning" and "continuous commissioning" (cf. Electrical and Mechanical Services Department, 2018a). According to Kubba (2016), a study conducted by the Lawrence Berkeley National Laboratory on 60 different building types found that: a) over 50% had control problems; ii) 40% had heating, ventilation, and air conditioning (HVAC) equipment problems; iii) 15% had missing equipment; and iv) 25% had building automation systems with economizers, variable frequency drives and advanced applications that were not operating correctly. To tackle these problems, the commonly used RCx measures are: 1) revise control sequence; 2) reduce equipment runtime; 3) optimize airside economizer; 4) add/optimize supply air temperature reset; 5) add variable frequency drive to pump; 6) reduce coil leakage; 7) reduce/reset duct static pressure set point; 8) add/optimize optimum start/stop; and 9) add/optimize condenser water supply temperature reset (Portland Energy Conservation Incorporated, 2010; Tiessen, 2017).

However, the uptake of RCx in existing buildings has doggedly remained limited, even though pilot projects (e.g., "ACT-Shop" RCx projects in Hong Kong) have expanded in recent years (Dodds et al., 2000; Construction Industry Council and Hong Kong Green Building Council, 2020). To identify future directions of works required for enabling wider adoption of RCx, relevant publications on standards and policy measures that are conducive to RCx implementation were reviewed in order to address the following research questions: What are the common barriers to the uptake of RCx? Are there any specific standards on RCx? Are there any policy measures applicable for boosting the adoption of RCx?

Methodology

To answer the above questions, an integrative review approach, which is useful when the purpose of the review is to combine perspectives to create new insights (Snyder, 2019), was adopted in this study. Apart from reviewing renowned RCx-related literature, statutes, and publications of public and professional institutions, an extensive search was made on the information resources of the International Organization for Standardization (ISO). Given that the US is at the forefront of introducing mandatory requirements on RCx (Law et al., 2020), a search was also made on the official websites of well-established US organizations that publish relevant standards, namely, American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The keywords "retro-commissioning" and its alternative form "retro-commissioning" were used in subsequent searches, but no results of standards/guidelines were obtained. Consequently, a further attempt was made using the keyword "commissioning" to search publications that are "Standard" (in the "Content Type" field) and "Most Recent" (in the "Document Status" field) on the website of ANSI. Extending the above search to cover content providers beyond the above four organizations (ISO, ANSI, ASTM and ASHRAE) found further documents with "commissioning" shown in their title, which were published by organizations including the British Standards Institution (BSI), the Canadian Standards Association (CSA) and the German Institute for Standardization (DIN). All such publications found were reviewed by manual content analyses where salient features and contents of the publications were identified and compared. Built upon the review findings, the way forward for enabling wider uptake of RCx is delineated.

Emergence and development of RCx

By virtue of the technological advancements in digital energy-efficient technologies (Edwards et al., 2017; Newman et al., 2020), more and more buildings have been designed and constructed as environmentally friendly (Elghaish et al., 2022). But the large energy demand of innumerable existing buildings remains a knotty issue. While retrofits have been well recognized as useful for improving building energy performance (Zhang and Lai, 2018; Sing et al., 2021; Ho et al., 2021), RCx has emerged as a viable alternative approach to enhance energy efficiency of existing buildings. According to a report of the Tokyo Metropolitan Government (2014), some geopolitical regions (such as the US and Hong Kong) have introduced government- or industry-led RCx programmes. In particular, some US cities have pioneered to impose stringent regulations on RCx (Institute for Market Transformation, 2021). A review on such regulations was in an earlier study (cf. Law et al., 2020); Table 1 shows an updated comparison between the statutory RCx requirements in the cities of Seattle, Los Angeles and New York. The requirements are different for different building types (e.g., commercial vs. non-commercial, public vs. private) and scales; the restriction on the timing of RCx (compliance cycle) also varies between these cities.

"Insert Table 1 here"

In Hong Kong, a wide range of building services regulations have been legislated (Lai and Yik, 2004; Lai et al., 2011); examples include: regular inspection of ventilating systems; and periodic inspection, testing and certification of electrical installations. Yet, RCx remains a voluntary measure for existing buildings. Over the past few years, the Hong Kong Government has adopted multi-pronged energy saving initiatives to reduce building energy use. The Electrical and Mechanical Services Department (EMSD) has actively promoted RCx by conducting pilot projects in government buildings and private buildings with the industry to serve as case study exemplars of savings to be made and performance improvements accrued. In 2018, the EMSD signed a memorandum of co-operation (MOC) with relevant institutions and universities in Guangdong, Hong Kong, Macao, Beijing and Shanghai to boost the development of RCx, marking a new chapter of energy efficiency policies (HKSAR Government, 2018).

In February 2019, the Central Committee of the Communist Party of China and State Council issued the development plan for the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) – this plan sets the GBA as a world-class, low-carbon economic hub, taking on a pivotal role in climate action (Legislative Council, 2019). The GBA contributed to 13% of the national GDP and accounted for 4% of the total national emission (Zhou et al., 2018). Being one of the top three cities with the lowest emission intensity in the GBA, Hong Kong could take lead to demonstrate how to effectively implement energy saving measures to mitigate carbon emission under massive urbanization and robust economic development. Thus, Hong Kong embodies the exemplification of a model city for energy saving in the region.

Barriers to RCx

Myriad benefits available from undertaking RCx include: improved system operation and equipment performance; enhanced knowledge and skill of operation and maintenance (O&M) staff; increased asset value; energy and cost savings; improved indoor environmental quality; improved building productivity; and improved building documentation (California Commissioning Collaborative, 2006; Environmental Protection Agency, 2009; Electrical and Mechanical Services Department, 2018a). Nevertheless, implementing RCx measures in existing buildings is not without difficulties; for instance, complexity of RCx measures and time constraint of O&M teams are proven barriers to RCx adoption (Smith and Hawksley, 2015). Significant upfront costs and uncertainty of energy savings that could be realized also discourage building owners from implementing RCx (Alliance to Save Energy, 2022). In addition, lack of RCx service providers could be a hindrance to making RCx common in existing buildings (Tiessen, 2017).

Barriers to energy efficiency in the building sector can be thematically categorised into four groups (Buildings Performance Institute Europe, 2011): 1) financial (e.g., payback expectations, investment horizons, competing purchase decisions); 2) institutional and administrative (e.g., regulatory and planning issues, multi-stakeholder issues); 3) awareness, advice and skills (e.g., information barrier, skills and knowledge related to building); and 4) separation of expenditure and benefit. Iwaro and Mwasha (2010) considered that the number of barriers to implementation of building energy regulation towards energy conservation and energy efficiency improvements is higher in the building sector than in any other sectors. These barriers include economic/financial barriers, lack of appropriate production technologies (LAPT), behavioral and organizational constraints, and information barriers.

In practice, a range of technical issues that hinder the adoption of RCx are commonly encountered (cf. Electrical and Mechanical Services Department, 2018a; 2018b):

1) Inaccuracy of sensors and/or insufficient sensors;
2) Excessively low temperature difference of main supply and return chilled water temperature;
3) Failure of chilled water zone control;
4) Condensation on surface of chilled water pipeworks and/or accessories;
5) Operating chiller capacity is greater than the required cooling load during cool climate;
6) Blockage of the condenser tube;
7) Air handling unit (AHU) fan with constant speed design only or variable air volume (VAV) control by fan inlet guide vanes or modulating damper (rather than variable speed drive);
8) Excessively low indoor air temperature (setting);
9) Indoor air distribution (unbalancing in VAV air supply system);
10) Air leakage from air duct;
11) Unsatisfactory cleanliness of air filter and/or cooling coil;
12) Incomplete or missing ductwork and pipework insulation; and

13) Review equipment operating schedules (lack of complete record).

Frequently, the upkeep of facilities (e.g., air-conditioning system) in buildings is constrained by limited budgets (Lai, 2010). Without sufficient RCx, the facilities would deteriorate, resulting in energy-inefficient operations and problems, such as failure of chilled water zone control and blockage of condenser tubes (Electrical and Mechanical Services Department, 2018b). In turn, the use of energy in buildings becomes excessive, making it difficult, if not impossible, to realize the goal of green buildings. As Figure 1 depicts, a fundamental reason for this phenomenon is the lack of RCx for the facilities.

"Insert Figure 1 here"

To overcome the barriers to the uptake of RCx, financial incentives should be offered (California Sustainability Alliance, 2012). Conversely, imposing penalties could be an alternative policy measure conducive to the adoption of RCx (Tiessen, 2017). Furthermore, various policy instruments (Howlett and Mukherjee, 2017) may be introduced to drive the implementation of RCx in the existing buildings. But before formulating or selecting an appropriate policy instrument, a more fundamental question is whether there is a standard of RCx works required. Moreover, these enabling levers are not mutually exclusive and could be used simultaneously in any combination.

RCx standard?

Building energy standards, which are crucial for reducing building energy use, have been applied mostly to new buildings (Ernest Orlando Lawrence Berkeley National Laboratory, 2012). To identify if there exists any international or well-established RCx standards for existing buildings, a series of searches, as described in the methodology section, was made on the information resources of the ISO, ANSI, ASTM and ASHRAE. Table 2 summarizes the search results, among which some are in fact manual/guidelines rather than standards.

"Insert Table 2 here"

With the above searches extended to cover content providers beyond the above four organizations found a total of 100 documents with "commissioning" shown in their title, and the additional content providers found include the British Standards Institution (BSI), the Canadian Standards Association (CSA) and the German Institute for Standardization (DIN). A document highly relevant to RCx is CSA Z5001:20 - Existing building commissioning for energy using systems. Published by the CSA, it is a national standard of Canada that intends to guide the commissioning process. It includes commissioning the components of energy/water systems and progresses to commission building systems and their integration to confirm that the building meets current requirements in the most optimal manner from an energy and water consumption standpoint (Canadian Standards Association, 2020).

The aforementioned discourse within pertinent literature illustrates that there are standards on commissioning, which are mainly tailored for newly completed buildings. These standards usually cover some particular facets of buildings (e.g., building enclosure, pumping installation, lighting system), instead of the complete RCx process for existing buildings. Although a national standard on existing building commissioning has been published in Canada, an international standard on RCx currently remains unavailable.

Potential policy measures

The continual increase in building energy consumption is a long-standing anthropogenic problem that has received intense attention from energy policymakers, practitioners and researchers (Rosenow et al., 2016). Among the plethora of energy policy publications, many focussed on reviewing or examining issues such as fuel types (e.g., coal, oil, nuclear, hydrogen) and conceptual frameworks for energy policy analysis from a macro-economic perspective (e.g., Griffin, 2009; Hamilton, 2013); the energy policy barriers identified (including the technical, geographical, economic, political and environmental ones) predominantly focus on energy resource conversion or distribution rather than those specific to energy use in buildings.

To break the barriers to attaining energy-efficient buildings, policymakers can choose to implement various policy alternatives, as summarized in Table 3 (Kraft and Furlong, 2021) viz.: 1) regulation; 2) government management; 3) education, information, and persuasion; 4) taxing and spending; and 5) market mechanisms. Policy instruments that serve as enablers for the promotion of building energy efficiency (Table 4), which can be classified into regulatory instruments, economic instruments and information tools (Organisation for Economic Co-operation and Development, 2003), are applicable to existing buildings (Lai and Yik, 2006). In principle, different types of policy instruments can serve different policy functions. As regards energy efficiency, a comprehensive study was conducted to analyse the interaction effects of the following policy types (Rosenow et al., 2016): 1) energy-efficiency obligations (EEOs); 2) energy or CO_2 taxes; 3) grants; 4) loans; 5) on-bill finance; 6) tax rebates; 7) regulations; 8) voluntary agreements; 9) standards and norms; 10) energy-labelling schemes; and 11) Information, advice, billing feedback, smart metering.

"Insert Table 3 here"

"Insert Table 4 here"

Besides the above policy instruments, there are policy mechanisms that may be used by policymakers. For example, Majchrzak (1984) notes that such mechanisms comprise a vast array of policy tools that fall into the following groups: information related; financial measures; regulatory and control measures; operation; policy related function; and research and development.

Discussions and future directions

The above review unveils the historical development of RCx and its recent state. Also identified from the review are the absence of an international standard on RCx and the policy measures that may be taken to promote the uptake of RCx. This leads to two main questions. First, is an international standard on RCx needed? Second, which of those potential policy measures is/are fit for application to RCx? The first question is discussed as follows.

Without an RCx standard, industry practitioners (especially facilities managers and engineers) would be free to adopt their own practice to carry out works required for RCx. Therefore, it is likely that their scopes of work would vary, and their levels of work might not meet prerequisite quality conformance standards for the purpose of RCx. The identification of existing work practices of the practitioners is essential because this establishes the basis upon which their extent and quality of works for RCx can be ascertained. Therefore, studies involving interviews, surveys, etc. on the existing FM work practices are urgently needed. From such study results, any obvious deficiency in the existing practices (e.g., malpractice), will be found. Yet, to determine whether the existing practices are up to the level required for RCx, it is imperative to establish a reputable standard on RCx for comparison with the existing practices.

To develop an RCx standard, the CSA's national standard (as elucidated upon previously) provides an invaluable opportunity as an experiential precedence on existing building commissioning for energy using systems (cf. CSA Z5001:20). Facts and encounters from that experience accrued reflective insight into: what initiated the development of that standard; who participated in the development process; how that process was conducted; and perhaps most importantly, how the contents of the standard were set and finalized.

Since energy reduction is among the essentials for achieving the United Nations SDGs (United Nations, 2022b), it is necessary to develop an international standard on RCx to help mitigate excessive building energy use. Indeed, the ISO has published various standards that contribute to the SDGs (International Organization for Standardization, 2018). Government (regulators) can base on the standards to create public policy that helps further the SDGs, industry can refer to the guidelines and frameworks set in the standards to work towards those goals, and consumers at the local community level can gain benefits from implementing the standards. To commence developing a new standard, it is important to adhere to two key principles (International Organization for Standardization, 2019): 1) market relevance (i.e., the standard responds to end users' needs and solves a problem faced by the market); and 2) stakeholder engagement (i.e., engage with all relevant stakeholders to secure their feedback).

An International Standard (IS), which is the target deliverable, can take different forms, e.g., test methods, codes of practice, guideline standards and management systems standards (International Organization for Standardization, 2020). Before a standard could be finalized, in some cases, a Technical Specification (TS) that addresses the work under development is published for immediate use, which also provides a means to solicit feedback. Different from the preceding two publications - IS and TS, a Technical Report including data obtained from a survey (as mentioned above) or information on the perceived "state of the art" may be published. This can serve as useful reference for the RCx stakeholders during the interim period. If RCx becomes an urgent market need, a Publicly Available Specification (PAS), upon obtaining the consensus of relevant RCx experts within the working group or a consensus in an organization external to the ISO, could be published for immediate use and serve as a means to obtain feedback for an eventual transformation into an IS (International Organization for Standardization, 2020).

To address the second question, multiple stages of future research work are required. Before the applicable policy measures for enabling wider adoption of RCx (i.e., enablers) could be determined, the barriers to RCx must be identified. Whereas several barriers have been identified in the above review, it is vital to further investigate the criticality of the barriers. This is because resources for policy formulation and implementation are quintessentially limited; only policies that can effectively surmount the paramount barriers should be adopted. To identify such barriers, future research work may include case studies or action research involving interviews and analysis of documents (Majchrzak and Markus, 2014; Yin, 2018) in the context of RCx. Such information collated would provide a factual account of RCx in practice (i.e., documents) and an explanation of the events that unfold (i.e., opinions accrued via interviews) – such would yield impactful knowledge upon which future potential policy measures is/are fit for application to RCx.

To further probe deeper into the "how" and "why" of a contemporary phenomenon (Burkholder, 2019), focus group studies with input from experts in the field will help (Krueger and Casey, 2014). The focus group participants should be representatives from key stakeholders (State and Local Energy Efficiency Action Network, 2013), including government (e.g., bureaus or authorities that formulate/implement public policy), building owners, FM companies, service providers and RCx experts. During such a stakeholder engagement exercise, the participants should be facilitated to analyse the critical RCx barriers, enablers and related policies. Among a variety of qualitative analysis techniques (Bryman and Burgess, 2002; Silverman, 2017), institutional analysis – a useful tool in understanding how communities manage resources and how improvements in management can be initiated (Langill, 1999) – can help assess the feasibility and any problems in implementing the potential policies measures (Figure 2). For measures considered as impracticable or worthy of re-examination, the participants should be invited to offer their opinions and discuss whether, and how, the measures should be adjusted.

"Insert Figure 2 here"

Upon finalizing the measures, the experts should be facilitated to discuss and advise how the enablers should be implemented. For each measure, the levels of effort (for implementation) and effect (after implementation) must be determined. Further analysis can be made by, for example, plotting the effort and effect levels on the Effort-Effect (EE) 2 x 2 Matrix in Figure

3, where four quadrants are indicated: 1) low effort, high effect (measures to be implemented with top priority); 2) high effort, high effect (measures to be implemented if resources are not constrained); 3) low effort, low effect (measures to be implemented if resources are limited); and 4) high effort, low effect (measures to be implemented with the lowest priority). The analysis results will inform the priority order of the enablers, based on which recommendations can be formulated for fostering wider adoption of RCx.

"Insert Figure 3 here"

In any case, development of a reputable standard and formulation of an appropriate policy must consider a broad range of factors. Varying geographically from place to place, such factors include not only those in the technical aspect but also the relevant cultural, social, legal, economic, environmental and political considerations. Undoubtedly, establishing an apt (indeed, universal) standard or policy takes a considerable period of time, let alone one that tailors for implementation in a large community – the existing building sector. Therefore, it is crucial to start working along the above directions without delay.

Conclusions

Green building design features and innovative construction technologies are widely available, and many voluntary and mandatory measures have been introduced across the world to foster a greener built environment that harmonises with the natural environment. However, countless existing buildings remain far from meeting the green building standard. RCx, as a knowledge-based systematic process that can improve existing buildings' environmental performance, is useful for realizing the goal of green buildings. However, hitherto its adoption in practice has yet to become common.

The above review recounts the emergence and development of RCx in places where efforts have been actively made to pursue energy-efficient buildings; such places include cities (e.g., Hong Kong, New York) in the two largest economies – China and the US. The paper also reviewed the key issues of RCx, including typical implementation barriers in existing buildings, standards around the world that are related to RCx and potentially applicable policy measures for boosting the adoption of RCx. Uncovered from the review are two niches: the lack of a specific RCx standard that is globally applicable, and the need for a bespoke policy or policy mix for driving the uptake of RCx.

Plugging the two niches entails the establishment of appropriate RCx standard and policy measures, for which further works are needed. Built upon the discussion on the foregoing review findings, future directions for developing the needed standard/policies have been identified, with the works for accomplishing these target deliverables also suggested. Besides engaging key government and industry stakeholders, contributions from academia and researchers, for example in undertaking relevant policy research studies, are essential. With a credible standard and an appropriate policy in place, RCx will be more widely adopted, making the existing buildings greener. This is an imperative issue given that buildings significantly contribute to anthropogenic emissions that lead to the global climate change – any delays in developing impactful solutions will defer the delivery of the United Nations SDGs. Moreover, the planet will be damaged irreparably – hence, this paper concludes with an urgent call for actions within the built environment academic and professional community.

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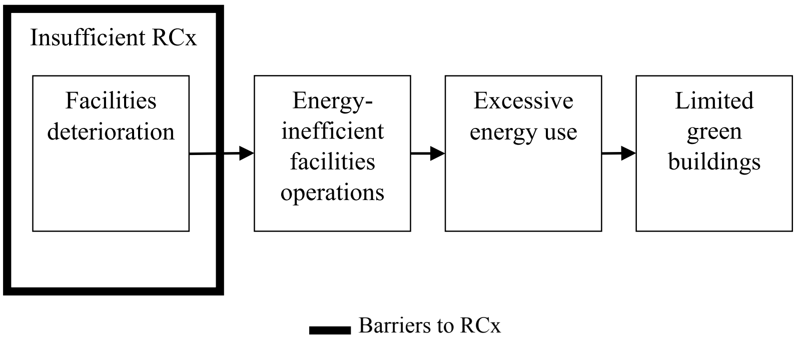

Figure 1 Conceptual model of the RCx problem

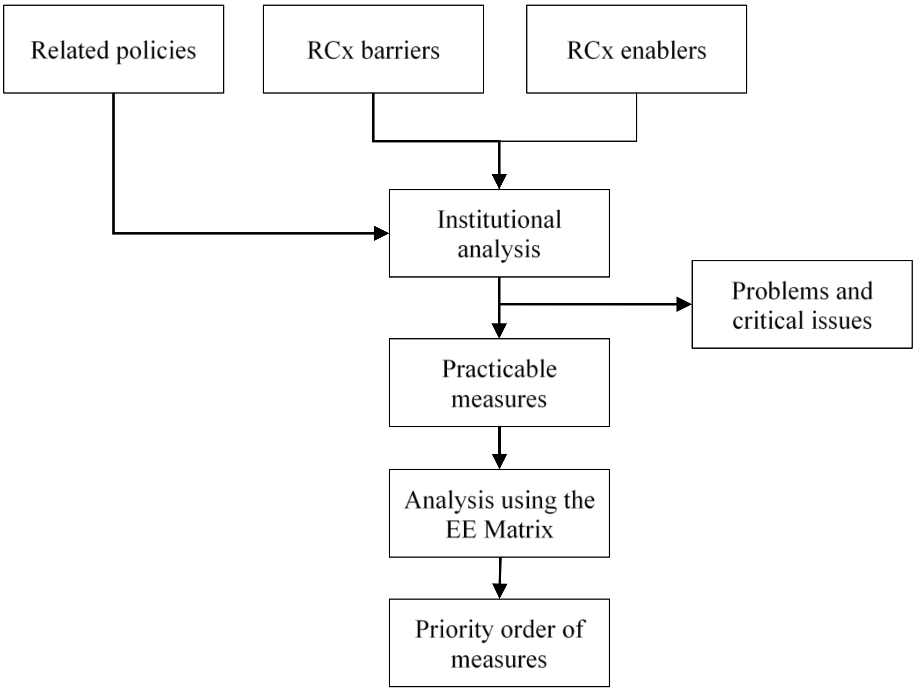

Figure 2 Analysis framework

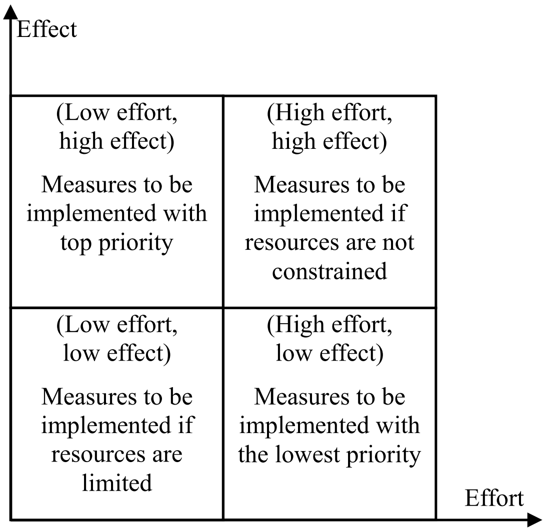

Figure 3 Effort-Effect Matrix

Table 1. Mandatory requirements on RCx

	Seattle	Los Angeles	New York
Relevant law	Building Tune-Ups, SMC 22.930	Existing Buildings Energy and Water Efficiency Program (Ordinance No.184674)	Local Law No. 87
Scope of regulation[1]	Commercial or city-owned buildings ≥ 50,000 ft^2	Publicly-owned buildings ≥ 7,500 ft^2; privately-owned buildings ≥ 20,000 ft^2	Buildings ≥ 50,000 ft^2
Length of compliance cycle	5 years	5 years	10 years

[1]Detailed scope or exemption criteria refer to the respective legal requirements.

Table 2. Publications of ISO, ANSI, ASTM and ASHRAE

Organization	Document
ISO	• ISO 19455-1:2019 - Planning for functional performance testing for building commissioning — Part 1: Secondary hydronic pump, system and associated controls. • ISO TS 21274:2020 - Light and lighting — Commissioning of lighting systems in buildings. • ISO 10784-1:2011 - Space systems — Early operations — Part 1: Spacecraft initialization and commissioning. • ISO 21105-1:2019 - Performance of buildings — Building enclosure thermal performance verification and commissioning — Part 1: General requirements. • ISO 7240-19:2007 - Fire detection and alarm systems - Part 19: Design, installation, commissioning and service of sound systems for emergency purposes. • ISO 3977-8:2002 - Gas Turbines - Procurement - Part 8: Inspection, Testing, Installation and Commissioning. • ISO 7240-14:2013 - Fire detection and alarm systems - Part 14: Design, installation, commissioning and service of fire detection and fire alarm systems in and around buildings. • ISO 10784-3:2011 - Space systems — Early operations — Part 3: Commissioning report.
ANSI	• ANSI/SMACNA 014-2013 - HVAC Systems Commissioning Manual
ASTM	• ASTM E2813-18 - Standard Practice For Building Enclosure Commissioning. • ASTM E2947-21a – Standard Guide For Building Enclosure Commissioning. • ASTM E2813-18 Red - Standard Practice For Building Enclosure Commissioning (Standard + Redline PDF Bundle). • ASTM E2947-21a Red - Standard Guide For Building Enclosure Commissioning (Standard + Redline PDF Bundle). • ASTM E3010-15(2019)e1 - Standard Practice For Installation, Commissioning, Operation, And Maintenance Process (ICOMP) Of Photovoltaic Arrays.
ASHRAE	• Guideline 0-2019 - The Commissioning Process. • Guideline 1.5-2017 - The Commissioning Process for Smoke Control Systems. • Guideline 0.2-2015 - Commissioning Process for Existing Systems and Assemblies. • Guideline 41-2020 - Design, Installation and Commissioning of Variable Refrigerant Flow (VRF) Systems. • Standard 202-2018 - Commissioning Process for Buildings and Systems (ANSI Approved; IES Co-sponsored). • Guideline 1.1-2007 - HVAC&R Technical Requirements for The Commissioning Process. • Guideline 1.2-2019 - Technical Requirements for the Commissioning Process for Existing HVAC&R Systems and Assemblies.

Note: Publications in languages other than English are not included in this table.

Table 3. Instruments of public policy

Instrument	Action	Examples
Regulation.	Government decrees that require or prevent individuals, corporations and other units of government from doing something.	• Laws enacted by the legislature. • Rules adopted by the bureaucracy.
Government management.	Implementation of services or management of resources directly to citizens.	• Education and defence. • Municipal services like police and fire protection.
Education, information, and persuasion.	Education of citizens in an attempt to persuade them to behave in a certain way.	• Appeal to support relief efforts after disaster. • Nutrition labelling to encourage healthy eating.
Taxing and spending.	The collection or expense of money to achieve policy goals.	• Social security to support the elderly in retirement. • Cigarette tax to discourage smoking and raise revenue for other programs.
Market mechanisms.	Use of the market to provide the public with incentives to make them choices or correct problems.	• Revenue-neutral carbon tax to discourage the use of fossil fuel. • Publication of the energy efficiency of appliances.

Table 4. Policy instruments (enablers) for existing buildings

Category	Policy instruments
Regulatory instruments.	Technology-based standards for O&M of buildings. Performance-based standards for O&M of buildings. Imposition of obligation on building owners.
Economic instruments.	Energy taxes. Tradable permit schemes. Capital subsidy programmes. Tax credit schemes. Premium loan schemes.
Information tools.	Energy audit programmes. Mandatory labelling schemes. Voluntary labelling schemes.