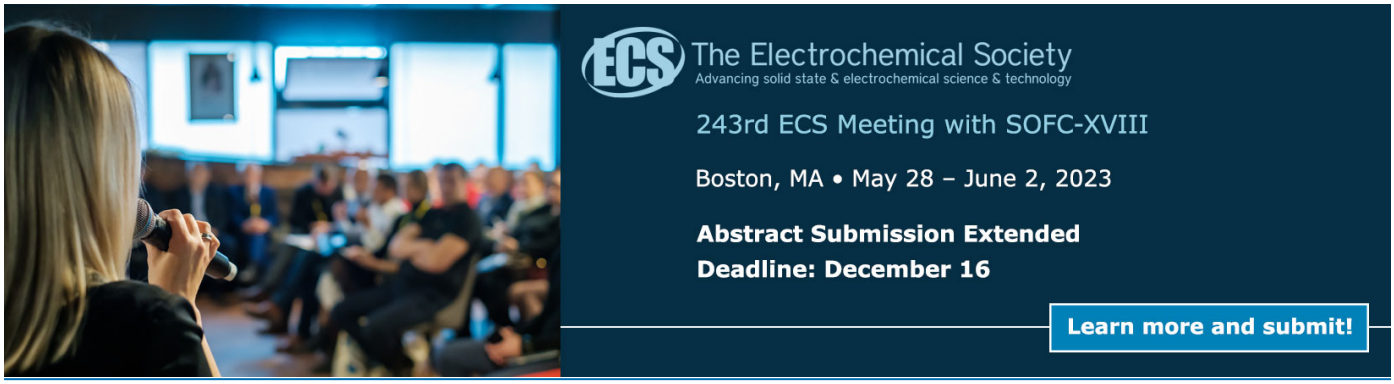
Retro-commissioning for buildings: problems and the way forward for a policy research study



Retro-commissioning for buildings: problems and the way forward for a policy research study

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Abstract. Buildings represent a major source of energy use and significantly contribute to carbon emissions and hence, the global warming problem. Towards the goal of sustainable and smart buildings, worldwide a variety of voluntary and mandatory tools have been introduced to enhance buildings' operational performance. Among these tools is retro-commissioning (RCx) - a knowledge-based systematic process to periodically check and improve existing buildings' performance. However, the uptake of RCx in the building sector remains limited. Grounded on a literature review, this paper reports on the emergence and development of RCx, a comparison between RCx programmes in cities that pioneered to impose regulations on RCx, the characteristics of RCx, and the concerns over the implementation of RCx in existing buildings. In addition, barriers and policy measures revealed from the building energy literature, which are potentially applicable to RCx, were identified. The way forward for a proposed study, by which appropriate policies can be identified to enable RCx implementation, is described. Findings from this study would serve as reference that imposes implications to future RCx research.

1. Introduction

Towards the goal of green buildings, worldwide a variety of voluntary and mandatory policies have been introduced to enhance the performance of buildings. Hong Kong, an Asian metropolis with a dense built environment, has been proactive in the pursuit of green buildings. For example, the Electrical and Mechanical Services Department (EMSD) and the Environmental Protection Department (EPD) jointly issued a set of guidelines in 2008 (then updated in 2010) to assist the users and managers of buildings to improve their awareness of greenhouse gas (GHG) emissions, measure their GHG emission performance, and actively participate in actions to combat climate change [1]. Apart from the introduction of this voluntary initiative, the Hong Kong Government enacted the Buildings Energy Efficiency Ordinance (BEEO) in 2012, which imposes mandatory requirements on building energy performance. Recognizing the need to expedite energy reduction, in recent years, the Government has further promoted the adoption of retro-commissioning (RCx) for improving

the performance of buildings in Hong Kong [2]. To date, however, the uptake of RCx in the existing buildings remains limited.

To investigate how RCx could be widely implemented, a research study is proposed. Underpinning this proposal is a review of the relevant literature, the findings from which, as reported in the following, include: emergence and development of RCx, characteristics and concerns of RCx, barriers to RCx, and measures that may be taken to circumvent the barriers. Then the research tasks required for the proposed study, to be undertaken in multiple stages, are described.

2. Emergence and development of RCx

Building energy standards, which are crucial for reducing building energy use, have been applied mostly to new buildings [3]. The large energy demand of existing buildings remains a problematic issue. In recent years, RCx has emerged as a policy trend over the world to deepen energy efficiency in buildings. In places such as Singapore, the U.S., the U.K. and Sweden, there are different RCx programmes led by the government or the industry [4]. Particularly, the U.S. has pioneered to impose regulations of RCx in cities such as New York, Los Angeles, and San Francisco. Comparisons of the requirements on these places, including the scope of regulation, implementation cycle, and criteria for exemption, etc., are summarized in Table 1 [5].

Table 1. Comparison between RCx requirements

	New York	**Los Angeles**	**San Francisco**
Relevant law	Local Law 87	Existing Buildings Energy and Water Efficiency Ordinance	Existing Commercial Building Energy Performance Ordinance
Scope of regulation[a]	Buildings ≥ 50,000 ft^2	City-owned buildings ≥ 7,500 ft^2, Privately-owned buildings ≥ 20,000 ft^2	Commercial buildings ≥ 10,000 ft^2
Implementation cycle	10 years	5 years	5 years
Criteria for exemption[1]	LEED 2009 for Existing Building; Buildings ≤ 10 years old, etc.	Energy Star-certified buildings, at least 25% better than median, etc.	LEED-certified buildings; Energy Star-certified buildings; New Construction with ≤ 5 years old
Max. payback period required for improvement[a]	≤ 7 years	Not applicable	≤ 3 years or ≤ 5 years

[a] Detailed scope or exemption criteria refer to the respective law.

In Hong Kong, a wide range of regulations have been enacted on building services [6-7]. Yet, RCx remains a voluntary measure for the existing buildings. Over the past few years, the Hong Kong Government has been pursuing multi-pronged energy saving initiatives to reduce energy use in

buildings. The EMSD has actively promoted RCx through conducting pilot projects at government buildings and private buildings with the industry. In November 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 [8].

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), which sets the GBA as a world-class, low-carbon economic hub, taking on a pivotal role in climate action [9]. The GBA contributed to 13% of the national GDP and accounted for 4% of the total national emission [10]. Being one of the top three cities with lowest emission intensity in the GBA, Hong Kong could take lead to demonstrate how energy saving measures could be effectively implemented to mitigate carbon emission under massive urbanization and robust economic development, stepping up to become a model city for energy saving in the region and even the nation.

3. RCx: characteristics and concerns

Facilities installed in buildings, including air-conditioning, electrical, and lighting installations etc., would deteriorate over time. With the aim of identifying operational improvements for such facilities (thus lowering energy costs) and improve the indoor environment, RCx is a knowledge based systematic process to periodically check an existing building's performance. Different from traditional commissioning (Cx) that mainly checks if the different components of a system are installed, quality-assured, and functional as stated in the design intent, RCx aims at guaranteeing the system running at the optimum and energy-efficiency condition throughout the operation [11].

RCx covers the scope of "existing building commissioning", "re-commissioning" and "continuous commissioning" [12]. According to [13], the work of [14] found that the commonly used RCx measures are:

- Revise control sequence;
- Reduce equipment runtime;
- Optimize airside economizer;
- Add/optimize supply air temperature reset;
- Add variable frequency drive to pump;
- Reduce coil leakage;
- Reduce/reset duct static pressure set point;
- Add/optimize optimum start/stop; and
- Add/optimize condenser water supply temperature reset.

Nevertheless, implementing RCx measures in existing buildings is not without difficulties. For instance, complexity of RCx measures and time constraint of operation and maintenance (O&M) teams are barriers to adoption of RCx in existing buildings [15]. Significant upfront costs and uncertainty of energy savings that could be realized also discourage building owners from getting RCx implemented [16]. Lack of RCx service providers, additionally, could be a hindrance to making RCx common in existing buildings [13].

To overcome the hindrances to the uptake of RCx, offering financial incentives should help [17], although imposing penalties could be an alternative policy measure [13]. Whereas various policy instruments [18] may be introduced to drive the implementation of RCx in the existing buildings, it is not certain which or which mix of the policy instruments is fit for Hong Kong.

4. Barriers and potentially applicable policy measures

It is encouraging to note the above initiatives and efforts in promoting RCx. Yet, it is not certain whether they effect an optimal policy setting [18] that augments the pursuit of sustainability of

the built environment. Globally and in Hong Kong, the deterioration of facilities (e.g. air-conditioning systems) in buildings has become a growing concern. Without sufficient RCx, the facilities deteriorate, resulting in problems such as failure of chilled water zone control, blockage of condenser tubes and so on [19] and hence energy-inefficient operations. In turn, the use of energy in buildings becomes excessive, making it difficult 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.

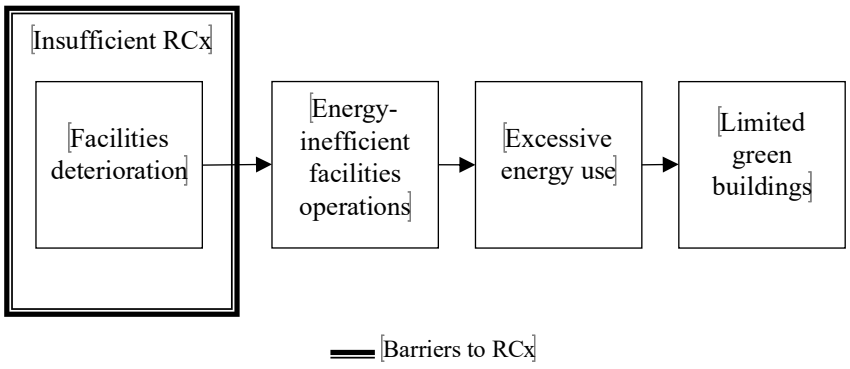

Figure 1. Conceptual model of the RCx problem

In fact, the continual increase in building energy consumption is a long-standing problem that has received intense attention of energy policymakers and researchers. Among the plethora of energy policy publications, many focussed on review or examination of 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. [20-21]); the energy policy barriers identified, including the technical, geographical, economic, political and environmental ones, are often about energy resource conversion or distribution rather than those specific to energy use in buildings.

As identified [22], barriers to energy efficiency in the building sector can be categorised as shown in Figure 2. According to [23], the number of barriers to implementation of building energy regulation towards energy conservation and energy efficiency improvements is estimated to be higher in the buildings sector than in any other sector. These barriers include economic/financial barriers, lack of appropriate production technologies (LAPT), behavioral and organizational constraints, and information barriers.

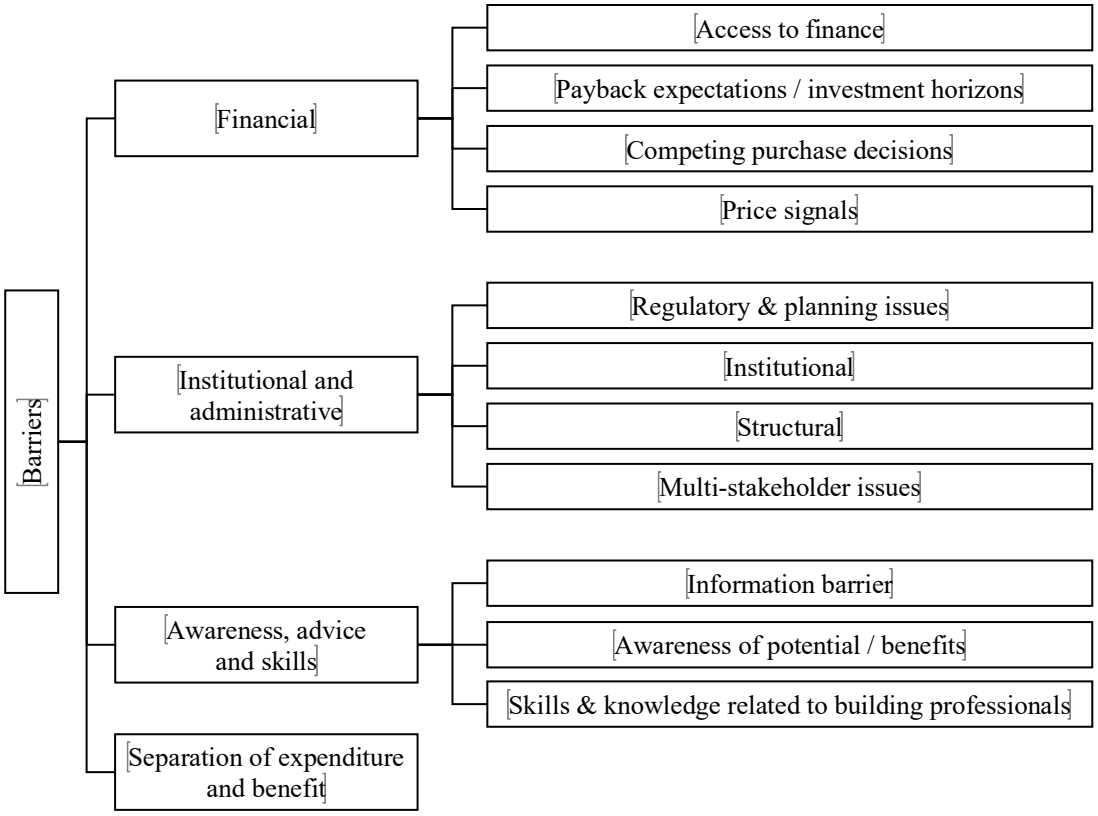

Figure 2. Barriers to energy efficiency in the building sector **[22]**

To tackle the barriers to attaining energy-efficient buildings, policymakers can choose among various policy alternatives, as summarized in Table 2 [24]: (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 3), which can be classified into regulatory instruments, economic instruments and information tools [25], are applicable to existing buildings [26].

Table 2. Instruments of public policy **[24]**

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 defense • 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 3. Policy instruments (enablers) for existing buildings **[26]**

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

The above barriers and enablers, including the policy instruments and mechanisms, are germane to building energy efficiency. Whether they are entirely applicable to RCx has yet to be ascertained, and this gives rise to a research question.

5. Research plan and methodology

To address the above question, a research study is needed. Among the many methods applicable to policy research [27], a mixed methods approach involving both qualitative and quantitative research methods is needed for the study. The tasks required for the study are outlined below.

5.1. Stage 1 – Desktop study/work

Further to the review of literature for preparing the current paper, a desktop study will be conducted to further search from the literature any new information that is useful to this study. Any new information so identified will be combined with the information found from the earlier literature review. After this process, three types of information will be consolidated: (1) common RCx measures; (2) barriers to adoption of RCx; and (3) enablers for adoption of RCx. Such information will be categorized, in a way similar to another work of the study team [28], to facilitate the design of a questionnaire for use in a later stage.

5.2. Stage 2 – Case studies

To gain in-depth knowledge of the issues under investigation and, particularly, to verify whether the RCx measures, barriers and enablers identified from the above stage exist in real-world buildings, case studies involving interviews and analysis of documents [27] will be conducted.

In these case studies, the study team will interview the representatives such as the facility managers of the respective buildings. For buildings with RCx implemented, the representatives will be requested to share their experiences and matters such as any incentives or enablers for the RCx works, RCx measures implemented, any problems encountered, how such problems were resolved, and costs and benefits of the RCx works. For buildings with no RCx completed, the representatives will be asked about any barriers to RCx or reasons for not implementing RCx, any measures they consider useful for enabling the adoption of RCx.

5.3. Stage 3 – Focus group discussion (first)

Upon completion of the above tasks, a focus group meeting will be organized to collect qualitative data from different perspectives [29]. Target participants of this meeting are RCx experts. Based on the RCx measures, barriers and enablers obtained in the previous stage, a series of guiding questions will be designed for use in this focus group meeting. To be held with experts in the field [30], the discussions in this meeting will be facilitated by the project team. Throughout the meeting, the project team will record the matters deliberated. Upon reaching a consensus of the participants, the finalized lists of measures, barriers and enablers will be incorporated into the questionnaire in the next stage.

5.4. Stage 4 – Questionnaire survey

To identify the existing adoption levels of RCx in the buildings and to investigate at what levels the O&M practitioners consider the RCx barriers and enablers as significant, a questionnaire survey will be conducted on the building O&M community. The questionnaire will be pilot-tested before use in a full-scale survey. Targeting practitioners working on existing buildings in Hong Kong, the questionnaire will be distributed to a wide spectrum of O&M practitioners. Data collected will be analysed to work out: the proportions and hence the levels of the RCx measures adopted for the buildings; the importance ranking of the barriers, based on which the significant barriers will be identified; the ranking of the enablers, based on which the crucial enablers will be identified.

5.5. Stage 5 – Focus group discussion (second) and institutional analysis

The findings obtained from the preceding stage, particularly the ranking of the enablers, will be discussed by a second focus group. The meeting for this focus group will be organized and convened in a way akin to that of the first focus group meeting: target participants will be RCx experts. During this focus group meeting, the study team will facilitate the experts to review the findings with institutional analysis, which is a useful tool in understanding how communities manage resources and how improvements in management can be initiated [31]. The institutional analysis will consider the related policies and the barriers and enablers identified above. The focus group experts will discuss the feasibility of implementing measures that can enable wider adoption of RCx; any problems and critical issues in implementing the measures will be identified. Upon finalizing the measures, the experts will be facilitated to discuss and advise how the enablers should be implemented. Afterwards, the priority order of the enablers will be determined, based on which recommendations will be formulated for fostering wider adoption of RCx.

6. Conclusions

Green building design features and construction technologies have been widely available, and many voluntary and mandatory schemes have been introduced across the world to foster a greener built environment. However, countless existing buildings remain far below the green building standard. Even though RCx, a knowledge-based systematic process that can improve the environmental performance of existing buildings, is useful for realizing the goal of green buildings, its adoption in practice remains uncommon.

The review above highlights the key matters of RCx, including not only the characteristics of RCx but also the common concerns and barriers to implemention of RCx. Policy measures that are potentially applicable to overcoming the RCx barriers have also been identified. Yet, it is necessary to determine which or which combination of these measures should be taken to form a policy that can effectively enable the implementation of RCx in existing buildings. For this purpose, a multi-stage research study, as desribed above, is essential for paving the way forward for greening the existing buildings. The resarch tasks requried include desktop literature review, cases studies, focus group dicussions, and institutional analysis of the barriers to, and enablers for, RCx implementation. The outcome of this study, viz. an appropriate policy for fostering wider adoption of RCx in existing buildings, would help attain a sustainable built environment.

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