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Review

Building Energy Governance: Statutes and Guides on Retro-Commissioning in China and the United States

Savannah Y. T. Lai [1], Joseph H. K. Lai [2,*], Philip Y. L. Wong [3] and David Edwards [4,5]

[1] School of Law, City University of Hong Kong, Hong Kong, China; savanlai2-c@my.cityu.edu.hk
[2] Department of Building Environment and Energy Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[3] Pan Sutong Shanghai-Hong Kong Economic Policy Research Institute, Lingnan University, Hong Kong, China; philipwong@ln.edu.hk
[4] Department of the Built Environment, Birmingham City University, Birmingham B4 7XG, UK; drdavidedwards@aol.com
[5] Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg 2006, South Africa
* Correspondence: bejlai@polyu.edu.hk; Tel.: +(852)-2766-4697

Abstract: Reducing building energy use, a linchpin of climate change mitigation, is a daunting challenge across the world. Gaining increasing attention, retro-commissioning (RCx) is a systematic process that can improve building energy performance. Using a techno-legal lens to review statutes and guides on RCx, this study reveals that in China, a national standard on building commissioning has taken effect yet RCx statutes are hitherto not found. The United States has RCx statutes enacted over 14 states; scrutinizing the statutes of five cities unveils similarities and differences in their scope of control and compliance requirements. In the absence of a specific RCx statute, the guide of Hong Kong, China provides detailed guidance for energy saving practices. While these findings can serve as reference for other places planning to formulate laws or guidance on RCx, the need to further study the effectiveness of mandating RCx for reducing building energy use is highlighted. A conceptual analysis of cost variation with statutory control, which could help policymakers consider from an economic perspective whether or to what extent statutory RCx requirements should be imposed, is also illustrated. This not only contributes insights to the pursuit of an optimal balance between statutory control and voluntary action for energy reduction but also adds to the debate on building energy policies.

Keywords: commissioning; energy; guide; law; policy; retro-commissioning

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1. Introduction

Continuous and substantial energy use in buildings results in excessive anthropogenic greenhouse gas emissions, contributing to the global environmental problems [1–3]. To reduce energy use and attain environmental sustainability, a multitude of policies and long-term policy pathways have been studied [4–6], but the GEG remains fragmented [7]. To enhance the security, stability and sustainability of the global energy order, research studies on GEG have emerged and this trend has continued to rise [8–10].

In the building sector, a plethora of energy research studies have been undertaken and numerous measures have been introduced to minimize energy use (e.g., [2,11]). For new buildings, notable efforts have been made to design and equip them with renewable energy systems and energy efficient facilities, such as high-efficiency heating, ventilating and air-conditioning systems, solar photovoltaic panels, wind turbine systems, energy efficient lighting (e.g., light-emitting diode light bulbs), and lift regenerative power systems [12,13]. While the past efforts tended to focus on energy-efficient technologies and new-builds [14],

buildings equipped with energy-efficient facilities that are not properly operated or maintained continue to overuse energy. To avoid this phenomenon, a critical stage of a building lifecycle is commissioning [15]. As a quality-focused process before building occupation, commissioning ensures that the building's facilities are tested to meet the requirements as intended by the building owner and as designed by the building architects/engineers [16]. However, not every building has undergone a thorough commissioning process [17] before handover to the FM team.

Even for buildings with a proper commissioning process completed before occupation, their facilities would age, with their operating efficiency and performance deteriorating over time [18]. Energy wastage is doomed to occur unless the facilities are commissioned again, viz. retro-commissioned or recommissioned, at appropriate times. More importantly, there are innumerable existing buildings across the world, which are major energy consumers. Providing existing buildings with RCx or recommissioning [19], therefore, is crucial for realizing the goal of energy reduction and environmental conservation.

RCx is a knowledge-based systematic process to periodically check and improve existing buildings' performance. For example, the common RCx tasks for an air-conditioning system include the following: revise the control sequence, reduce equipment runtime, and optimize the airside economizer [20,21]. But without standardized governance, the practice of RCx could differ between buildings and vary from place to place. Many buildings remain without proper RCx, despite the proven benefits of RCx [17,22]. To boost the uptake of RCx in existing buildings, statutory requirements such as those governing building services maintenance [23] or voluntary schemes (e.g., carbon emission reporting [24]) promoted through the promulgation of guidelines may help [25].

Worldwide, a variety of energy laws, including state-based laws on building energy, have been enacted [26,27] and legal research in this area has expanded [28,29]. There have been review studies on building energy laws (e.g., [30,31]), Renewable energy legal frameworks and laws (e.g., [32,33]), and built environment sustainability guidelines (e.g., [34]). Recently, a review has also been made on RCx standards and policy [35], but scant research has taken a cross-disciplinary lens to examine both the legal and technical aspects of RCx. In-depth reviews of statutory requirements or guidance on RCx, from which implications on building energy policies could be revealed, are even absent from the literature.

Against the above backdrop, the following research questions arise. First, are there any statutes governing RCx? If such statutes exist, second, what are their key features? Third, alongside the statutes, are there any guides that provide detailed provisions on how to implement RCx? If such guides exist, how do they compare with each other? Finally, what energy policy implications could be found from exploring these questions? To this end, a review study was pursued, with its scope focusing on the contexts of China and the United States (US)—the world's two largest economies as well as having notable cultural and social symbolizations.

2. Materials and Methods

Figure 1 illustrates the steps taken in this study and the corresponding sections of this paper. At the beginning, searches were conducted to identify any laws (e.g., ordinances and regulations) on or related to RCx in China and the US. Given that New York and San Francisco are US cities with mandatory RCx requirements imposed [36] and with reference to the comparison of US RCx policies made by the Institute for Market Transformation [37], a further search was undertaken to identify any statutory RCx requirements enacted in other US cities including Seattle, Los Angeles, and Philadelphia. For these search processes, the official websites of the government agencies, authorities, etc., of the above places were inspected and Lexis Advance, which is a legal research search engine that hosts an extensive content source and incorporates the latest legislation, was also used.

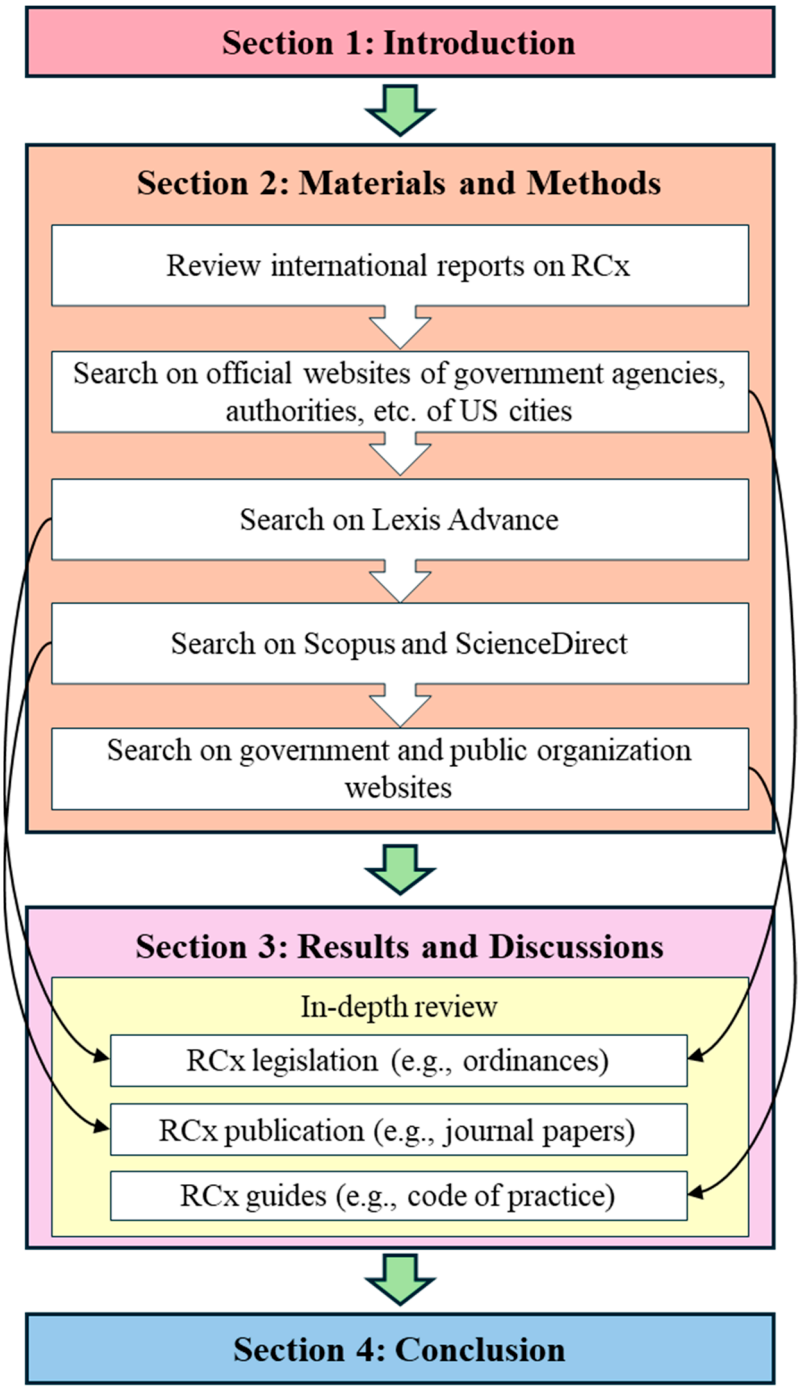

Figure 1. Flowchart of the research steps and structure of this paper.

As discourse between lawyers and scientists would lead to outputs of co-production in environmental policy [38], an extensive search was further conducted on two renowned literature databases: Scopus and ScienceDirect. The former is the largest peer-reviewed literature database covering legal and technical publications; the latter covers publications in disciplines including energy and management, which are within the focus of the present study. The keywords used in this search process include "retro-commissioning" and its alternative form "retrocommissioning". Hence, publications since 2000 containing these keywords in their title, abstract, or keywords field were retrieved. Table 1 summarizes the number of these publications; it shows that the word "retro-commissioning" is more commonly used than "retrocommissioning".

Table 1. Number of publications retrieved from the keyword search.

Keyword Used	Scopus	ScienceDirect
Retrocommissioning	55	3
Retro-commissioning	103	14
Total	158	17

The title and abstract of the 175 publications retrieved were perused. Most of these publications focus on engineering research into building energy, e.g., application of retro and on-going commissioning tools [39], development of an automated building commissioning analysis tool [40], and identification of building operational problems and energy saving opportunities [41]. Another group of the publications embraces handbooks that cover building commissioning (e.g., [42,43]). A further batch of the publications comprises articles on the practical issues (e.g., [44,45]). A paucity of the literature reported on efforts and programs that promote RCx (e.g., [17]). Publications on RCx-related requirements such as energy audits [46] were limited.

While statutes are mandatory, guides typically provide detailed guidance leading to good practices; in some cases, pursuant to certain clauses in the statutes, the guides (sometimes called codes of practice, manuals, etc.) set out standards for which statutory compliance is required. One example is the Code of Practice for Energy Efficiency of Building Services Installation [47]. Therefore, a further search process was conducted to identify guides on or related to RCx. Information identified from this process and those above were scrutinized and compared. Emergent findings were examined, as reported in the ensuing sections.

3. Results and Discussion

3.1. Any RCx Statute in China?

Among the aims of China's energy policy from 2011 onwards (Twelfth and Thirteenth Five-Year Plans) is climate change mitigation [48], and green energy is within the focus areas of the current Five-Year Plan (2021–2025) of China [49]. Besides the various energy conservation and efficiency policies that have been introduced in different Chinese cities [50,51], regulations on industrial energy efficiency and building energy conservation have been enforced [52,53].

China's policies related to building energy conservation are in three levels: (i) national laws approved by the Standing Committee of the National People's Congress, (ii) regulations of the State Council approved by the State Council in the form of the State Council's order, and (iii) department rules, standards, and plans approved by ministries and departments under the State Council. According to Yuan et al. [52], there are national laws and regulations related to building energy conservation in China (Table 2). To boost the development of RCx, relevant institutions and universities in Beijing, Guangdong, Hong Kong, Macao, and Shanghai (e.g., Building Energy Conservation Research Center of Tsinghua University, Hong Kong Green Building Council) signed a Memorandum of Cooperation in 2018, marking a new chapter of energy efficiency policies [54]. Insofar as the study could obtain from the above search processes, there were no specific statutes on RCx.

3.2. RCx Statutes in the US

According to the International Foundation for Electoral Systems [55], statutes are enacted by the legislative branch of government and regulations are a form of delegated legislation. In the context of the present study, written laws including ordinances, regulations, etc., imposing mandatory requirements belong to the domain of statutes. Among the studies on such statutes in the US, Seyrfar et al. [56] examined the effect of the building energy benchmarking regulations in seven cities. But review studies on statutes governing building RCx are currently unavailable within the extant literature. The foregoing litera-

ture search found that statutory RCx requirements had been enacted in various US cities. Examples of such well-known places that are among the largest cities in the US, from west to east, are the following: CSF, CS, CLA, CP, and NYC.

Table 2. National laws and regulations in China related to building energy conservation.

National Laws	Regulations
• Energy Conservation Law. • Cleaner Production Promotion Law. • Renewable Energy Law. • Circular Economy Promotion Law. • Construction Law.	Provisional Regulation of Management for Energy Conservation. Regulation on the Administration for Environmental Protection of Construction Projects. Regulation on Quality Management of Construction Projects. Regulation on Energy Conservation of State-funded Institutions. Regulation on Energy Conservation of Civil Buildings.

3.2.1. NYC

The Greener, Greater Buildings Plan, enacted in 2009 with the aim of reducing carbon emissions in NYC's existing buildings, comprises four pillars of energy efficiency-related regulations. LL87–Energy Audits and Retro-Commissioning, being one of the four pillars, mandates that buildings over 50,000 ft^2 shall undergo a periodic energy audit and RCx in a 10-year cycle and that building owners shall conduct energy audits which are not below the ASHRAE Level II. Thus, LL87 not only intends to deepen the building owners' understanding of the buildings' performance but also drives the transformation towards high-performance buildings.

LL87 stipulates that (i) early compliance is allowed within four years prior to the compliance date, (ii) an energy auditor shall be a registered design professional, and (iii) an RCx agent shall be a registered design professional, a certified refrigerating system operating engineer, or a licensed high-pressure boiler operating engineer. The authorized RCx agents are required to discharge RCx or certify RCx reports in order to comply with the rules promulgated by the NYC Department of Buildings. Chapter 100 of the Rules of the City of New York, akin to a code of practice, provides additional details on the compliance with LL87 and specifies the requirements of analysis, correction, and testing of different building systems or equipment for compliance.

3.2.2. CSF

Enacted in 2011, the Existing Buildings Energy Performance Ordinance of CSF gathers information for building owners' decision-making on the improvement of building energy efficiency and reduction in utility costs. This Ordinance requires existing non-residential buildings of 10,000 ft^2 or above to report their energy use annually and undergo energy audits every five years to identify cost-effective energy-saving measures.

For the energy audits under the Ordinance, non-residential buildings greater than 50,000 ft^2 shall meet ASHRAE Level II, while those of 10,000 ft^2 to 49,999 ft^2 shall meet ASHRAE Level I. Such an audit shall be conducted by an energy efficiency auditor, who can be a licensed engineer, the AEECEM, a building operating engineer, a chief operating engineer, or a party with equivalent professional qualifications and specialized training as determined by the Director and set forth on the Department of Environment website.

3.2.3. CS

The goal of the 2013 Seattle Climate Action is to reduce emissions from all commercial buildings by 45% by 2030 and achieve carbon neutrality by 2050. Echoing this goal, the BTU SMC 22.930 was legislated in 2016. The Office of Sustainability and Environment [57] published Rule 2016-01, which includes a clarification of the ordinance's requirements on the following aspects: (i) buildings and spaces; (ii) tune-up assessments, corrective actions, and reporting; (iii) compliance extensions and exemptions; and (iv) qualifications for tune-up specialists.

BTU's compliance cycle length is five years for city-owned and commercial buildings of 50,000 ft^2 or greater. The tune-ups require both mandatory and voluntary corrective actions for building energy and water tune-ups and shall be performed by a tune-up specialist such as a licensed professional engineer. BTU targets the compliance of private buildings, whereas the city-owned buildings are governed by the Municipal Building Tune-Ups Resolution (31652). The Seattle City Light's EBCx incentive program was launched in 2021. Under this program, participants may submit the Seattle City Light Application form, which acts as an opt-in system, to indicate whether they would like to implement the traditional RCx (Path A) or the monitoring-based commissioning (MBCx) (Path B) in the compliance of their buildings [58].

3.2.4. CLA

Under Los Angeles Municipal Code, Chapter IX, Article 1, Division 97, the EBEWE Program seeks to reduce energy and water consumption in buildings and lower greenhouse gas emissions citywide. Passed in 2017, the EBEWE Program includes two pillars: (i) annual energy and water benchmarking and reporting, and (ii) energy and water audits and RCx. It requires publicly owned buildings of 15,000 ft^2 or above and privately owned buildings of 20,000 ft^2 or above to undergo an energy audit, a water audit, and RCx every five years. Such energy audits, water audits, and RCx shall be performed under the direct supervision of a California-licensed engineer or architect. For energy audits to meet the statutory requirements, ASHRAE Level II must be attained.

Under the EBEWE Program, RCx shall be performed as per industry-standard practices, including the ASHRAE Guideline 0.2 Commissioning Process for Existing Systems and Assemblies. RCx for the base building systems shall include, at minimum, the following: (a) HVAC systems and controls; (b) indoor lighting systems and controls; (c) water heating systems; and (d) renewable energy systems. To fulfill the conditions under Section 22.930.060 of the EBEWE Program, building tune-ups and reports to be submitted to the City Council shall address ten building elements: (1) bill analysis, (2) sensors, (3) schedules, (4) set points, (5) outside air control, (6) equipment controls, (7) maintenance check, (8) design issues, (9) lighting, and (10) domestic plumbing system maintenance.

3.2.5. CP

Passed in 2020, the BEPP of CP aims to achieve efficient energy and water use in large non-residential buildings. CP projects that use BEPP will cut carbon pollution by nearly 200,000 metric tons, equivalent to taking 40,000 automobiles off the roads. Under the BEPP, buildings have three compliance options: (i) conduct a "tune-up" of existing building systems, (ii) certify high performance, and (iii) receive an exemption.

The BEPP requires the owners of non-residential buildings of 50,000 ft^2 or more to conduct regular building inspections and tune-ups through engaging a qualified tune-up specialist, such as a Licensed Professional Engineer or Certified Energy Manager [59], who has at least seven years of combined educational and professional experience with commercial building operations and/or building energy management [60]. Extensions and alternate compliance plans for high performance (in place of tune-ups) may be accepted.

3.3. Comparison between the US Statutes and Discussion

3.3.1. Time Difference in Enactment

Among the above US cities, the earliest one (in 2009) with an RCx statute enacted is NYC, followed by CSF, CS, and CLA (see Table 3). Over a decade after NYC's implementation of LL87, CP enforced the BEPP in 2020. This shows the significant time differences in enacting the RCx statutes in the five places even though they are all situated on the same continent—North America.

Table 3. Comparison of RCx between five US cities.

City/State ‡	**New York City/NY**	**San Francisco/CA**	**Seattle/WA**	**Los Angeles/CA**	**Philadelphia/PA**
Year enacted	2009	2011	2016	2017	2020
Relevant law	Local Law No. 87 (LL87)	Existing Buildings Energy Performance (EBEP) Ordinance	Building Tune-Ups (BTU), SMC 22.930	Existing Buildings Energy and Water Efficiency (EBEWE) Program	Building Energy Performance Policy (BEPP)
Scope of control (on real estate †)	COM and M $\geq$ 50,000 ft^2 PUB/G $\geq$ 50,000 ft^2	COM $\geq$ 10,000 ft^2 PUB/G $\geq$ 10,000 ft^2	COM and C $\geq$ 50,000 ft^2	PUB/G $\geq$ 15,000 ft^2 COM and M $\geq$ 20,000 ft^2	COM $\geq$ 50,000 ft^2 PUB/G $\geq$ 50,000 ft^2
Length of compliance cycle	10 years (early compliance is allowed within four years prior to the compliance date)	5 years	5 years	5 years	5 years
Requirements: Tune-up	Not specified	Not specified	Mandatory and voluntary corrective actions for building energy and water tune-ups.	Not specified	Extensions and alternate compliance plans for high performance (in place of tune-ups) may be accepted.
Requirements: Energy audit	ASHRAE Level II	10,000–49,999 ft^2: ASHRAE Level I; >50,000 ft^2: ASHRAE Level II	Not specified	ASHRAE Level II	Not specified
Requirements: Water audit	Not specified	Not specified	Not specified	Required	Not specified
Qualified professionals	Energy auditor: ■ Registered design professional §. ■ RCx agent: ■ Registered design professional §, or ■ Certified refrigerating system operating engineer §, or ■ Licensed high-pressure boiler operating engineer §.	Energy efficiency auditor: ■ Licensed engineer §, or ■ Association of Energy Engineers Certified Energy Manager (AEECEM) §, or ■ Building operating engineer §, or ■ Chief operating engineer §.	Qualified tune-up specialist: ■ Licensed professional engineer.	Energy audit, water audit, and RCx shall be performed under the direct supervision of a California-licensed engineer or architect.	Qualified tune-up specialist: ■ Licensed Professional Engineer, or ■ Certified Energy Manager.

Detailed requirements refer to the respective laws. § Conditions apply. † Real estate type: COM = commercial; C = city-owned; G = government; M = manufacturing; PUB = public; PVT = private. ‡ State: NY = New York; CA = California; WA = Washington; PA = Pennsylvania.

A plausible factor leading to the time differences in enacting the statutes is the federal government system established by the US Constitution. Under this system, the structure of state court systems varies from state to state; each of the 50 states in the US has its own state constitution, governmental structure, legal codes, and judiciary [61]. Another factor lies in the procedures of passing a bill in the US, which include the following: (i) sponsoring a bill by a representative from the US House of Representative; (ii) assigning the bill to a committee for study; (iii) getting the bill (if released by the committee) voted on, debated, or amended; (iv) moving the bill (if passed by simple majority (218 of 435)) to the Senate where the bill is assigned to another committee and, if released, debated and voted on; (v) passing the bill (if with a simple majority (51 of 100)); (vi) working out the final version

of the bill for final approval; (vii) printing the revised bill in enrolling; and (viii) signing (by the President) the enrolled bill [62]. Under normal circumstances, the process of passing a bill should not be more than one year, excluding the time taken for consultation, but this depends on the type and content of the bill concerned. It can be as short as several weeks, but the bill can also "die on the vine". In short, the length of time for passing a bill is potentially a complicated question given the multiple uncontrollable variables such as the complexity of the bill and the attitudes of the committee members.

3.3.2. Statute Title

All the five cities named their laws differently albeit the statutes govern the same matter—RCx. Named most straightforwardly is NYC's LL87—"Law"—followed by CSF's EBEP Ordinance—"Ordinance". CLA labels its RCx law as a "Program", which may confuse its statutory nature with the non-mandatory nature of some other programs (or campaigns). For instance, foreign building investors who are unfamiliar with the US legal system may perceive that the EBEWE Program has no legal binding effect. While titling the RCx legislation as "Policy", the BEPP of CP is in sooth a statute. Similar puzzlement may also arise when one reads the title of the RCx statute of CS—"Building Tune-Ups"—as its literal meaning is not obviously statutory.

Law is essentially a generic term, and different legal terms are used to indicate different sources of authority for the issuance of the corresponding policies by which the concerned institution governs. By legal terminology, statutes are laws enacted by legislatures. In the US, federal statutes are published as public and private laws and as codified law [63]. Unlike a federal statute, an ordinance is a local law that is passed by municipal governing authorities, such as a city council or county board of commissioners. Ordinances apply only to the local jurisdiction, and they provide an enforcement measure including penalties. Conversely, an individual state's administrative codes are created by an office or agency of the state under authority granted by the legislature. These codes have the force of law and consist of rules and regulations that interpret the requirements of an office or agency of the state [64]. The implementation and enforcement process, where penalties and agents vary, depends on the laws or regulations, notwithstanding that the statutory and administrative code requirements might be alike and are equally legally binding. A policy, defined as "a system of laws, regulatory measures, courses of action and funding priorities concerning a given topic promulgated by a governmental entity or its representatives" [65], is used broadly to include laws, rules, and regulations intended to accomplish certain goals. Therefore, to determine whether a piece of legal document (regardless of its title) is legally binding or not, it is imperative to consider its statutory definition, legal interpretation, context and structures, purpose, and legislative history [66].

Globally, different legal jurisdictions may have different interpretation systems of the legislatures. This can be exemplified by the case of Hong Kong, China. When interpreting the laws, Hong Kong legal practitioners follow the legal definitions stated in each individual piece of ordinance. If ambiguities or uncertainties are encountered, the practitioners could refer to the Interpretation and General Clauses Ordinance (Cap. 1) to seek clarifications and interpretation guidance. The US, however, has different theories, tools, trends and multiple sets of interpretation systems, which comprise numerous documents, systems, and references. The US lawyers, for instance, may use the "Major Theories", namely "Purposivism" and "Textualism", for statutory interpretation. The "Major Theories" aside, they may utilize the "Canons" such as the *Canons of Construction*, *Semantic Canons*, and *Substantive Canons* [67].

3.3.3. Scope

The RCx laws of both NYC and CP impose governance on commercial and public/government buildings of 50,000 ft^2 or larger; a slight difference in the building types governed is that NYC extends to require manufacturing buildings to undergo RCx. The scope of CSF's RCx requirements, similar to those of NYC and CP, covers commercial

and public/government buildings of 10,000 ft^2 or above. Governing commercial and city-owned buildings of 50,000 ft^2 or bigger, the scope of control on RCx in CS is comparatively the narrowest. CLA is well known for its comprehensive building energy efficiency standards [68]. The EBEWE Program imposes RCx requirements on public/government buildings of 15,000 ft^2 or more and commercial and manufacturing buildings of 20,000 ft^2 or above.

The types of buildings governed differ between the cities, but the rationale behind the differences is not documented in the statutes. In principle, the control on RCx should be more stringent for buildings that are more energy-intensive, such as buildings with long or even round-the-clock operations (e.g., hotels). In reality, however, imposing governance on government buildings instead of private-owned or operated buildings faces much lower resistance. Another difference in the regulatory controls between the cities lies in building scale. Again, the reason for this is not specified in the statutes. The considerations taken when setting the different thresholds on building size, which might have been deliberated during the consultation exercise before law enactment, may include the ease of building management and size demarcations stipulated in other but related statutes.

3.3.4. Length of Compliance Cycle

Except NYC, all the other four US cities prescribe the same length of the RCx compliance cycle—five years. NYC's LL87 requires building owners to conduct RCx once every ten years. In this sense, most of the cities under review impose more stringent regulatory control on RCx, whereas the counterpart of NYC is relatively lenient. Note, however, should be taken that NYC provides allowance for early compliance within four years prior to the compliance date.

While the rationale behind the five- or ten-year setting is not documented in the statutes, in principle, such a setting should be determined considering the energy performance of the facilities subject to RCx. The extent and quality of maintenance work provided for the facilities are crucial to the upkeep of their energy efficiency: the better the maintenance work, the longer the period before the facilities' energy efficiency drops to an unacceptable level. Life expectancy factors, such as those published by the Chartered Institution of Building Services Engineers [69], can also serve as reference in determining the compliance cycle settings.

3.3.5. Tune-Up Requirements

Tune-ups are opportunities that address the improvements needed for a building and its FM team: increased asset value, increased productivity, and reduced maintenance and operating expenses. Normally, tune-ups involve the following: (i) benchmarking utility costs, (ii) analyzing existing heating/air-conditioning and lighting control algorithms and schedules, (iii) conducting site investigations to spot check the performance of existing heating/air-conditioning and lighting energy management system equipment and instrumentation, and (iv) reviewing undocumented plug load equipment such as personal fans and other powered devices [70].

Different from CS and CP, the other three cities (NYC, CSF, and CLA) do not specify the requirements for tune-ups. As for CS, mandatory and voluntary corrective actions for building energy and water tune-ups are required. In CP, 6-month extensions and alternate compliance plans which are due 270 days prior to a building's compliance deadline for high performance may be accepted [59]. This shows that, with detailed requirements and conditions for conducting tune-ups stipulated in their respective RCx statutes, both CS and CP impose stringent control on buildings' tune-ups.

3.3.6. Energy Audit Requirements

An energy audit is an analysis and inspection of the energy usage in a facility, which helps to identify energy conservation measures for reducing the energy input into a building system without negatively affecting the output [71]. In practice, energy audits are carried

out based on standards such as those established by the ASHRAE. The three levels of ASHRAE energy audit standards are: (i) Level I—a walkthrough analysis, (ii) Level II—an energy survey and analysis, and (iii) Level III—a detailed analysis of capital-intensive modifications [72].

While the RCx laws of both CS and CP do not specify requirements on energy audits, NYC's LL87 and CLA's EBEWE Program state the same criteria on energy audits—ASHRAE Level II. CSF's EBEP Ordinance stipulates that buildings shall achieve a specified ASHRAE Level in the energy audit. These energy audit requirements, imposed by the three cities (NYC, CLA, and CSF), may offset the tune-up requirements specified for buildings in the other two cities.

3.3.7. Water Audit Requirements

Aiming to establish improved water conservation and link to the implementation of a water loss reduction plan [73], a water audit (i) determines the amount of water lost due to leakage, storage overflow, meter malfunctions, and theft; (ii) estimates the cost associated with the water loses; and (iii) offers the water system a detailed profile of the distribution system and water users which can allow for more effective management of resources. The EBEWE Program of CLA specifies water audit requirements, which are not stated in the RCx laws of the other four cities.

§91.9706.2.1. of the EBEWE Program provides the following:

> "**Water audits and retro-commissioning shall be performed** in accordance with industry standard practices, including ASHRAE Guideline 0.2 *Commissioning Process for Existing Systems and Assemblies*, and under the direct supervision of a California licensed engineer or architect." (emphasis supplied)

Similar to energy, water is a natural resource that should be used sparingly. Places with a less abundant water supply, for example, those with long drought periods, are more concerned about water use/wastage and, thus, have more governance imposed on water audits. Even for places with little concern about the water supply, requiring buildings to undergo water audits can help detect any water loss/wastage. This can avoid unnecessary water pump operations, thereby minimizing energy use.

3.3.8. Qualified Professionals

NYC, CSF and CLA specify the requirement of an energy or energy efficiency auditor. Unlike the usual requirement that licensed engineers are needed to carry out energy audits (e.g., in CSF), LL87 of NYC states that an auditor could be a registered design professional.

§28-308.1 of LL87 states the following:

> "An approved agency authorized by the department to perform energy audits and to certify audit reports required by this article. Until such time as there is a national standard establishing qualifications for persons performing energy audits and such standard has been adopted by the department, **an energy auditor shall be a registered design professional with such other certification or qualification as the department deems to be appropriate**..." (emphasis supplied)

As regards the identity of a registered design professional, the Office of the Professions of the New York State Education Department [74] sets out the CEPP and introduces a set of instructions of how to file a Professional Service Entity in NYC.

Section V of the CEPP provides the following:

> "A design professional is defined as an individual licensed and registered in New York as an architect, landscape architect, professional engineer, geologist, or land surveyor." (emphasis supplied)

Both CS and CP specify the requirement of a qualified tune-up specialist. To become such a specialist in CS, one needs to be a Licensed Professional Engineer, while in CP, a Certified Energy Manager can also be a qualified tune-up specialist.

Among the five cities, only NYC prescribes the requirement of an RCx agent. This party needs to be a registered design professional, a certified refrigerating system operating engineer, or a licensed high-pressure boiler operating engineer. The latter, for example, is usually a professional with a mechanical engineering background [75]. For RCx works beyond this engineering discipline, a professional with relevant knowledge and skills may need to be engaged.

Whereas the above cities generally require certain professionals to conduct the audits or RCx, CLA has a specific requirement under the EBEWE Program: energy audits, water audits and RCx shall be performed under the direct supervision of a California-licensed engineer or architect. To qualify as a California-licensed architect or engineer, one needs to satisfy a range of conditions required by the California Architects Board [76] and the California Board for Professional Engineers and Land Surveyors [77], respectively.

The review above, which covers five US cities, reveals differences in the statutory requirements on RCx. The experiences in legislating the RCx laws in these places are useful reference if similar statutes are to be formulated for other cities; note that only 14 of the 50 US states have enacted laws to govern RCx [37]. Before embarking on such legislative processes, however, it is necessary to study issues such as cultural differences, political considerations, and characteristics of the legal systems of the states and cities concerned. Besides these issues, in sooth, the law-making process is typically lengthy and the procedures involved, such as public consultation and debates over the bills, are often cumbersome. For example, it took a long period to legislate Tobacco 21 (T21) across the US. NYC legislated T21 in 2013 [78] and the law took effect in 2014 [79]. After NYC's movement, the City of Boston [80], the City of Chicago [81], the City of San Francisco [82], the State of California [83] and the State of Washington D.C. [84] enacted their T21 legislations in succession. Likewise, enacting RCx laws widely to drive energy reduction should be humanly possible in the future.

3.4. Guides on RCx

The foregoing section has examined the RCx statutes of five US cities. In China, a diverse range of national and industrial standards related to building energy conservation have been promulgated [52], but none of them impose specific governance on RCx. In 2021, China's Ministry of Housing and Urban-Rural Development issued standards on energy conservation and renewable energy use in buildings, which are the country's first compulsory national standards covering carbon emissions from buildings [85]. Effective from 1 April 2022, these standards consist of mandatory clauses; in particular, GB 55015-2021 "General Specifications for Building Energy Conservation and Renewable Energy Use" mandates that centrally conditioned public buildings of over 100,000 m^2 have to commission their HVAC systems [86]. Instead of governing RCx specifically for existing buildings, this requirement applies to installations in new buildings.

Hong Kong, a Special Administrative Region of China, has long established a series of Testing and Commissioning (T&C) Procedures. For example, the first edition of the T&C Procedures for air-conditioning installation was issued in 2002. Covering 12 different trades of installations [87], the Procedures set out the minimum T&C requirements on the respective installations in government buildings. Such requirements, for example, those on air-conditioning systems [88], are applicable to both new installations upon completion and the existing ones after major alteration. Nevertheless, for RCx for existing buildings, no statutes have been enacted in Hong Kong; in lieu, a set of guidelines [89] has been published to facilitate building owners and practitioners to perform RCx works. Below is a review of this document and two RCx guides in the US.

3.4.1. Retro-Commissioning Process Manual—Veterans Affairs

Most of the technical research on RCx was undertaken by government organizations such as the US Department of Energy, the California Energy Commission, and other state universities [90]. The VA, a public agency of the US, is among the pioneers to adopt RCx. Its

RCx Process Manual states the following drivers for conducting RCx: (i) the performance needs of healthcare and critical facilities; and (ii) the desire to obtain certification of the LEED program and the Green Globes program. Both these two green building programs are nationally accepted in the US. The Green Globes rating system, administered by the Green Building Initiative [91], has completed an American National Standard using an ANSI-approved consensus process. This is one of the main differences between the two green building programs [92].

The manual provides guidance for all federal government facilities under the Energy Independence and Security Act of 2007 (EISA) and states the following orders and regulations as the base of authorities: (i) Section 508, Rehabilitation Act of 1973; (ii) EISA; (iii) Executive Order 13423–Strengthening Federal Environmental, Energy, and Transportation Management (January 2007); (iv) Executive Order 13514–Federal Leadership in Environmental, Energy, and Economic, Performance (April 2010); and (v) Sections 543 and 548(a) of the National Energy Conservation Policy Act (NEPCA, 42 U.S.C. 8258(a)). In particular, the manual highlights that the RCx process is mandated under Section 432 of the EISA: "covered" federal facilities must undergo Energy and Water Efficiency evaluations and RCx on a four-year cyclical basis.

The manual delineates that, while buildings comprise static systems (e.g., building envelope and structure) and dynamic systems (e.g., HVAC, power, and elevators), the objective of the commissioning process is to address the building's integrated dynamic performance. The primary considerations in determining which building systems to commission are driven by the impacts of any given system on the overall performance of the building. Budgets for RCx projects, as stated, are created on a case-by-case basis and depend on the available funding. Implicitly, the projects are subject to budget constraints.

Covering the planning, acquisition, and performance of RCx, the majority of the manual's contents describe six stages of RCx works: (i) contract planning; (ii) planning; (iii) investigation; (iv) implementation; (v) turnover; and (vi) persistence. While no rigid time frame is specified for the warranty period of projects and "systems performance monitoring" is briefly discussed [90], the manual states that the commissioning agent, VA staff, and representatives of the accident and emergency team and the contractor team should verify on-going system performance during the warranty period [93]. Coyner and Kramer [90] submitted that the typical period for federal construction contracts is one year. But according to the Facilities Standards for the Public Buildings Service [94], different facilities have their specified warranty periods.

3.4.2. California Commissioning Guide: Existing Buildings

In accordance with the "State of California Green Building Action Plan, March 2005: Detailed Direction that accompanies Governor's Executive Order S-20-04. Section 1.1.2.1." [95], RCx is an effective way to meet energy efficiency goals. Published by the California Commissioning Collaborative [96], the California Commissioning Guide contains information drawn from several other guides to commissioning and retro-commissioning, including ASHRAE Guideline 0-2005: The Commissioning Process [97], *Retrocommissioning Handbook for Facility Managers* [98], and the *Practical Guide for Commissioning Existing Buildings* [99], to name just a few.

With building owners, managers and others involved in the RCx process as the target readers, the guide is not a how-to manual for RCx; instead, it provides the essential information for any party considering an RCx project, including the following: (i) introduction to the basics of RCx; (ii) benefits and costs of commissioning existing buildings; (iii) composition of an RCx team; (iv) different stages of an RCx process; and (v) strategies for ensuring persistence of RCx benefits.

Since financial considerations are quintessentially crucial to decision-making, the guide explains the benefits and costs of RCx in detail. Regarding the benefits, not only energy efficiency is emphasized, but improved indoor air quality, comfort, controls and other resources' efficiency are elaborated. As regards the costs, the guide points out that

variables including building size and the scope and complexity of RCx work are influential, and it indicates the range of costs reported in a study of 106 RCx projects [100].

Further to delineating the roles and responsibilities of the necessary members in an RCx team, the guide describes the tasks required for the four phases of work (planning, investigation, implementation, and hand-off) for an RCx process. Following these phases defined in the guide, Parrish et al. [101] pointed out that the RCx process should be designed with reference to building characteristics and stressed that during the planning stage, the RCx scope should be decided. This emphasis supports that a substantial proportion of the RCx cost is allocated to planning and investigation, as indicated in the guide.

3.4.3. Technical Guidelines on Retro-Commissioning (Hong Kong)

In 1998, the Hong Kong government's Electrical and Mechanical Services Department (EMSD) launched the voluntary "Energy Efficiency Registration Scheme for Buildings" to promote building energy efficiency. In 2012, the government enacted the Buildings Energy Efficiency Ordinance (Cap. 610), which imposes mandatory requirements on building energy efficiency. In the same year, the EMSD published the Code of Practice for Energy Efficiency of Building Services Installation and the Code of Practice for Building Energy Audit, both of which were later updated in 2021 [47]. The former document provides technical guidance on the minimum energy efficiency requirements governing the building services installations defined in the Ordinance [102]; the latter sets out the counterpart on energy audit requirements [103].

In parallel, the government promulgated in 2015 its target of achieving an energy intensity reduction by 40% by 2025, with 2005 as the base year. Apart from building energy retrofits [104,105], RCx is recognized as a useful tool for energy savings [106]. In 2016, based upon some pilot RCx projects, the EMSD drafted an RCx technical guide, which was launched in 2017 [107]. With feedback from various professional bodies and stakeholders taken, the EMSD updated the draft guide to become the "Technical Guidelines on Retro-commissioning" (TG-RCx) in 2018 [90].

With detailed guidance for RCx and information checklists/forms (e.g., Building Design and Operational Information Checklist, Current Facilities Requirements Form) provided, the contents of the TG-RCx cover the main building services facilities including the chiller plant, heat rejection system, water-side system, air-side system, electrical system, lighting system, and lift and escalator. Under this TG-RCx, four stages of RCx works, viz. (i) planning, (ii) investigation, (iii) implementation, and (iv) ongoing commissioning, are defined. While the details of building enclosure commissioning are not found in the guidelines, the building envelop is among the input parameters for the preliminary analysis of energy modeling, which forms part of the supplementary information of the guidelines.

Examples of ESO for air-conditioning systems, electrical systems, lighting systems, etc., which are commonly identified during an RCx process, are illustrated in the guidelines. To ensure that the benefits of RCx are maintained beyond the completion of an RCx process, the guidelines emphasize the importance of ongoing commissioning and recommend, from the building owner's perspective, strategies for keeping improvements made from RCx efficient over time. This echoes the note of Coyner and Kramer [90]: building owners are the beneficiary of RCx; they gain the most from RCx if the RCx process continues.

Key features of the above three guidance documents are compared in Table 4.

3.5. Comparison between the Guides and Discussion

The above three guides share similar goals—to provide guidance on RCx implementation for built facilities. However, the two US guides are issued based on certain statutes (Act or Executive Order) while the one of Hong Kong refers to the government's Energy Saving Plan [106], which has no legal binding effect on individual buildings' energy performance.

Table 4. Comparison between RCx guides.

	Retro-Commissioning Process Manual—Veterans Affairs (RCx PM-VA)	**California Commissioning Guide: Existing Buildings (CCG-ExB)**	**Technical Guidelines on Retro-Commissioning (TG-RCx)**
Version (year)	2010	2005	2018
Aim	This Manual offers guidance in meeting the mandate (EISA), and provides guidance for the planning, the acquisition, and the performance of Retro-Commissioning in VA facilities.	Written for building owners, managers, and others involved in the RCx process, this guide provides the necessary foundation for anyone considering an RCx project.	As there is no single defined guideline for building owners in Hong Kong on implementing RCx, this set of guidelines is designed to serve as basic and clear procedural guidance on RCx.
Relevant authorities	Authorities cited: 1. Section 508, Rehabilitation Act of 1973 2. Energy Independence and Security Act of 2007 (EISA) 3. Executive Order 13423—Strengthening Federal Environmental, Energy, and Transportation Management (January 2007) 4. Executive Order 13514—Federal Leadership in Environmental, Energy, and Economic 5. Performance (April 2010) 6. Sections 543 and 548(a) of National Energy Conservation Policy Act (NEPCA, 42 U.S.C. 8258(a)).	Order referenced: 1. State of California Green Building 2. Action Plan, March 2005—Detailed 3. Direction that accompanies Governor's 4. Executive Order S-20-04. Section 1.1.2.1: "In California, state-owned buildings are required to reduce their energy 5. Consumption by at least 20% by 2015."	Plan referenced: 1. Energy Saving Plan for Hong Kong's Built Environment 2015~2025+ published by Environment Bureau in collaboration with Development Bureau and Transport and Housing Bureau in May 2015.
Registered parties	No registered party but "RCx Contractor" is recommended for undertaking the RCx work.	No registered party but a "commissioning lead" (an independent third-party contractor (commissioning provider) or a member of the owner's staff) is recommended for undertaking the RCx work.	No registered party but a "building owner's O&M staff (if capable) or RCx service provider (outsourced)" is recommended for undertaking the RCx work. Moreover, a registration scheme of RCx Practitioners, RCx Professionals, and RCx Services Providers has been introduced by the Hong Kong Green Building Council.
Number of RCx stages	Six (Phase 1—VA Contract Planning; Phase 2—RCx Planning; Phase 3—RCx Investigation; Phase 4—RCx Implementation; Phase 5—RCx Turnover; Phase 6—RCx Persistence).	Four (Stage 1: Planning; Stage 2: Investigation; Stage 3: Implementation; Stage 4: Hand-Off).	Four (Stage 1: Planning; Stage 2: Investigation; Stage 3: Implementation; Stage 4: Ongoing Commissioning).

Table 4. *Cont.*

	Retro-Commissioning Process Manual—Veterans Affairs (RCx PM-VA)	California Commissioning Guide: Existing Buildings (CCG-ExB)	Technical Guidelines on Retro-Commissioning (TG-RCx)
Examples of ESOs	Not illustrated.	Not illustrated.	Examples for systems/installations including the following are illustrated: 1. Air-conditioning (central chiller plant); 2. Air-conditioning (heat rejection system); 3. Air-conditioning (air-side system); 4. Air-conditioning (water-side system); 5. Electrical system; 6. Lighting system.
Standard procedures/ forms	No standard procedures of RCx works are specified, but sample forms are provided (e.g., Appendix G "Sample Systems Testing Forms" of the Manual) and the Procedural Standards of the National Environmental Balancing Bureau [108] are cited.	No standard procedures of RCx works are specified, but a list of reference resources (e.g., Title 24 containing California's Energy Efficiency Standards for Residential and Nonresidential Buildings) and a section describing the meaning and benefits of the test protocol are provided.	No standard procedures of RCx works are specified, but sample forms/checklists are provided, e.g., "Current Facilities Requirements Form" and "Building Walk-Through Checklist."

TG-RCx is different from the two US guides in that it provides a recommendation for the parties to be engaged in RCx works: either the building owner's O&M staff (if capable) or an RCx service provider (outsourced). In this connection, the Hong Kong Green Building Council [109] has introduced a registration scheme of RCx Practitioners, RCx Professionals, and RCx Services Providers. The detailed requirements of such parties, including training, examination and the registration fee required, are shown in a handbook [110]. On the other hand, the requirements of the parties to be appointed for undertaking RCx works are specified in the statutes of the respective US cities. As reviewed earlier, for example, Seattle requires that an RCx agent is a registered party (e.g., registered design professional). Common to the three guides, stakeholders other than the registered parties, such as the building owner and O&M staff, are regarded as key players towards the success of RCx. This echoes the proposed establishment of a broad-spectrum team, which ensures that the RCx objectives are achieved with good relationships and communication between the stakeholders [111].

All the three guides recommend that an RCx process should cover the planning, investigation, and implementation stages. RCx PM-VA, additionally, emphasizes the inclusion of a contract planning stage at the beginning of an RCx process; the guidance on turnover (Phase 5) is similar to that on hand-off (Stage 4 of CCG-ExB). Essentially the same as Phase 6 (RCx Persistence) under RCx PM-VA, Stage 4 (Ongoing Commissioning) under TG-RCx stresses the importance of energy savings' persistence after the completion of RCx. Notwithstanding these recommendations, an RCx project in reality is rarely a linear process. It is not uncommon to implement an RCx phase (or stage) of work for a certain trade while some other trades are still being investigated. For example, a complicated air-conditioning system takes longer than a simple lighting system to undergo the investigation phase for RCx. Therefore, further guidance is needed to address such coordination issues between different trades of RCx works.

In particular, CCG-ExB provides a unique recommendation that the scope of RCx includes other services such as prioritizing and scheduling deferred maintenance work. While engineers and facility managers may investigate the possibilities of integrating retrofits and equipment replacement works with RCx, the guide sets out the advantages and disadvantages of including retrofits as part of the RCx works in the four RCx stages: planning, investigation, implementation, and hand-off. As remarked in CCG-ExB, the primary objective of commissioning for a retrofit project is much the same as the counterpart for a new construction.

Consistently mentioned across all three guides is the involvement of building owners, as their decisions on RCx projects are typically made from an investment perspective and the upfront cost for RCx is a common financial barrier. The two power companies in Hong Kong [112,113] have set up funds to subsidize building owners in implementing RCx projects that enhance building energy efficiency. Subsidies granted, for instance, may be used to improve the energy efficiency of communal building services installations, e.g., lighting, air-conditioning, lift, escalator, and electrical installation. In the US, local governments work with electric utilities to design efficiency programs for homes and businesses and to improve the efficiency of their own facilities [114].

On top of financial incentives, return on investment (estimated based on costs and benefits) is a quintessential metric for project decision makers. While the tasks and checklists provided in the above guides are useful information for cost–benefit analyses, RCx planners can refer to the list of energy saving opportunities (ESOs) in TG-RCx [89] when studying the financial viability of RCx projects. However, examples of ESOs are not shown in the two US guides.

No standard procedures of RCx works are specified in the three guides, but RCx PM-VA refers to the procedural standards of the National Environmental Balancing Bureau [108] in addition to providing some sample forms for the works. Likewise, TG-Rx also provides sample forms to facilitate the implementation of RC works. Instead of standard forms, reference resources related to RCx (e.g., Title 24 containing California's Energy Efficiency Standards for Residential and Nonresidential Buildings) are listed in CCG-ExB.

With no RCx standards established in Hong Kong, TG-RCx refers to standards including ASHRAE 90.1-2013 [115] and ISO 17741:2016 [116], which are some international standards or standards of the US instead of the national standards of China. This is an example manifesting the upkeep of the constitutional principle "One Country, Two Systems" of China on the governance of Hong Kong.

Essentially, the information contained in the three guides is meant to be guidance leading to good practices. It is reasonable to expect that RCx professionals will adapt the information (sample forms, procedures, etc.) to suit the RCx works for individual buildings. Before any RCx statute is enacted, as in Hong Kong, FM practitioners should be encouraged to follow the guide to carry out RCx works. Since doing so is still voluntary, it is not certain to what extent RCx will be implemented in the existing buildings. Future work, therefore, should investigate the prevalence of RCx adoption and evaluate the energy reduction progress against the planned energy saving target.

Although no RCx statutes have been enacted in Hong Kong, it is plausible that mandatory RCx requirements will be imposed in future. Take the Building Energy Code [102] as an example, initially, it was introduced as a voluntary measure, but later, compliance with its requirements became a mandate under the Buildings Energy Efficiency Ordinance (Cap. 610). With reference to such similar precedents, introducing a new legislation to require buildings to undergo RCx is likely to encounter resistance from stakeholders, especially when viewed from an economic perspective, as positive environmental attitudes and willingness to building energy conservation are typically outweighed by cost considerations [117]. Whereas it is not straightforward to empirically measure the costs associated with statutory control, Figure 2, adapted from Lai [118] and as explained below, illustrates a conceptual analysis.

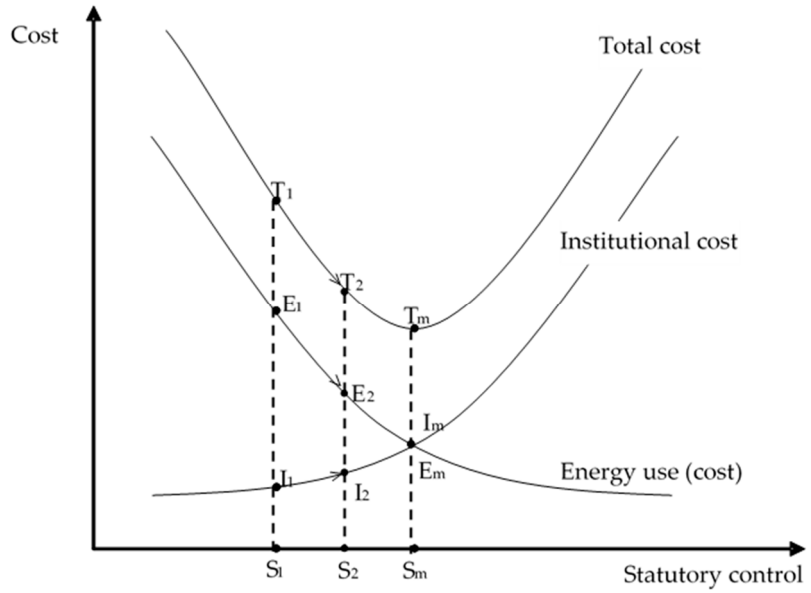

Figure 2. Costs' variation with statutory control.

Imposing more statutory control on RCx (moving from S_1 to S_2) would reduce building energy use, i.e., less energy cost (moving from E_1 to E_2). But more institutional costs (moving from I_1 to I_2), including the part on the government for formulating, administering and enforcing relevant statutes and the part on the parties under control for taking compliance actions, would be incurred [23]. With an effective statutory control, the drop in energy cost (E_1-E_2) would outweigh the rise in institutional cost (I_2-I_1), resulting in a decrease in the total cost (T_1-T_2). Further tightening the control (S_m) would attain an economic optimum, i.e., minimum total cost (T_m); but if the increase in the institutional cost continues to escalate while the energy cost reduction diminishes, the total cost would rise. This conceptual analysis can assist policymakers in considering whether, or to what extent, statutory control on RCx should be imposed.

4. Conclusions

Despite the notable efforts made to design and construct energy-efficient buildings, the substantial energy use of a myriad of existing buildings remains a daunting challenge in climate change mitigation. RCx, a systematic process that can improve the energy performance of buildings in use, has emerged as a measure conducive to the enhancement of GEG. While the existing body of building energy laws and legal research in this area have continued to grow, few have taken a multi-faceted perspective to examine both the legal and technical issues of building energy reduction measures. The study reported in this paper addresses this research gap through an in-depth review of the RCx statutes and guides in China and the US.

As reviewed, several implications arise. First, green energy remains a focus area of China's energy policy, with various energy conservation and efficiency regulations continually enforced over the past decades. A national standard on commissioning has been introduced, but specific statutes governing RCx are yet to be seen. Further policy research is needed to investigate the progress and contribution of the existing buildings' energy efficiency improvement towards the carbon neutrality goal and thus ascertain whether it is necessary to make RCx mandatory in places where RCx laws are not yet enacted.

Second, 14 states in the US have RCx laws enacted. Such statutes in five US cities (NYC, CSF, CS, CLA, and CP) were examined and the cross comparisons made identified similarities and differences in the following: timing of enactment; statute title; scope of control; length of compliance cycle; requirements on tune-up, energy audits, and water

audits; and qualified professionals specified for undertaking RCx works. Not only can these findings ameliorate puzzlements or confusions among stakeholders such as building investors and practitioners who are unfamiliar with the institutional settings of different US cities, but they also serve as a reference for policymakers who plan to introduce similar statutes in the future; albeit, issues such as cultural differences, political considerations and characteristics of the legal systems of different places should be evaluated collectively before embarking on the typically lengthy legislative process.

Third, the reviews and comparisons on the three guides (RCx PM-VA, CCG-ExB, and TG-RCx) in the US and Hong Kong showed that similar aims are enshrined in the guides. Among the key differences between the guides is that in the absence of an RCx statute, the Hong Kong guide (TG-RCx) provides significantly more guidance details. Registration schemes for RCx Practitioners, Professionals and Services Providers have also been introduced to augment the implementation of RCx. While such registration provisions are not meant to be compulsory, it is not costless to establish, operate, and maintain the registration systems. Whether it is effective to keep promoting and encouraging the voluntary uptake instead of mandating RCx to reduce building energy use, therefore, is a question that warrants further exploration.

Fourth, worth investigating too is the effectiveness of the US regulatory control on RCx towards building energy reduction. For policymakers of nations or cities considering from an economic perspective whether, or to what extent, statutory RCx requirements should be imposed, the foregoing conceptual analysis can help, even though garnering the needed empirical data is not straightforward.

Mindful of the imperfections of this study, the findings are limited by the ways in which the literature and official information including statutes and guides were searched and analyzed. While the study's context is focused on the two largest economies in the world, any experience of governance imposed by other countries on RCx may also add to the debate on building energy governance, thereby advancing the pursuit of an optimal balance between statutory control and voluntary action for energy conservation. Looking forward, endeavors should be made with these constraints addressed when future research attempts to provide insights that complement those reported above.

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Acronyms and Abbreviations

AEECEM	Association of Energy Engineers Certified Energy Manager
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers Inc.
BEPP	Building Energy Performance Policy
BTU	Building Tune-Ups
CCG-ExB	California Commissioning Guide: Existing Buildings
CEPP	Corporate Entities for Professional Practice
CLA	City of Los Angeles
CP	City of Philadelphia
CS	City of Seattle
CSF	City of San Francisco
EBCx	Existing Building Commissioning
EBEWE	Existing Buildings Energy and Water Efficiency
ESO	Energy saving opportunities
FM	Facilities management
GEG	Global energy governance
HVAC	Heating, ventilation, and air conditioning
LL87	Local Law 87
MBCx	Monitoring-based commissioning
NYC	New York City
O&M	Operations and maintenance
RCx	Retro-commissioning
RCx PM-VA	Retro-Commissioning Process Manual—Veterans Affairs
T&C	Testing and commissioning
TG-RCx	Technical Guidelines on Retro-commissioning
VA	Department of Veterans Affairs

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