The state of the art of the existing tools for building retrofitting

Estado del arte de herramientas para el reacondicionamiento ambiental de edificios

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Resumen
El reacondicionamiento ambiental de edificios existentes ofrece oportunidades significativas para reducir el consumo de energía global y las emisiones de gases de efecto invernadero en el área de la construcción. Por lo tanto, se considera uno de los principales enfoques para lograr la sostenibilidad en el entorno construido a un costo relativamente bajo y con altas tasas de aceptación. Aunque existe una amplia gama de tecnologías de mejoramiento disponibles, los métodos para identificar las medidas más rentables para cada proyecto siguen siendo un desafío técnico importante. Numerosos proyectos han sido desarrollados en todo el mundo para enfrentar este desafío, sin embargo, muchas de las herramientas tienen una aplicación local, por lo que muchos de estos proyectos son desconocidos en el ámbito internacional, resultando en una limitada transferencia de conocimiento. Esta revisión organiza los resultados en tres categorías: evaluación de la renovación, financiera y transferencia de información. Por otro lado, se considera que las herramientas para promover la renovación de edificios difieren de acuerdo al usuario, por ejemplo, los propietarios necesitan recomendaciones para renovar sus propios edificios, mientras que otras herramientas se centran en proporcionar información a nivel general a políticos e inversores a una escala de información mayor, señalando las áreas donde existe un potencial de renovación energética o para el uso de fuentes de energía renovables. Finalmente, se presentan herramientas para evaluar las viviendas existentes que buscan registrar y caracterizar los edificios. Estas herramientas comúnmente llamadas herramientas de certificación tienen diferentes grados de sofisticación y de enfoques. La revisión muestra que muchas herramientas tienen el potencial de unir sus capacidades, lo que puede generar muchas oportunidades de innovación en el área del reacondicionamiento ambiental de edificios.

Palabras claves: herramientas de avaluación de reacondicionamiento ambiental, certificación de edificios, evaluación energética de edificios.

Abstract
The retrofitting of existing buildings offers significant opportunities to reduce global energy consumption and greenhouse gas emissions in the build environment. Therefore, it is considered as one of the main approaches to achieve sustainability in the built environment at a relatively low cost and high acceptance rates. Although there is a wide range of retrofitting technologies available, methods to identify the most cost-effective measures for each project remain a major technical challenge. Numerous projects have been developed worldwide to face this challenge with different approaches; however, many of the tools meet only local objectives, which is why they are unknown in the international arena, showing a limited knowledge transfer. This review organizes the results under three categories: renovation assessment, financial assessment and Transfer of knowledge. The tools focusing on promoting the renovation of buildings differ in the type of user to whom the tool targets for example, the owners need information and recommendations to renovate their own buildings. Where other tools focus on providing information to politicians and investors were the scale of information is greater, pointing out areas where an energy potential that can be improved through renewal or the use of renewable energy sources is highlighted. Finally, other tools to comply with policies that seek to register, evaluate and characterize the existing buildings. These tools commonly called certification tools, have different degrees of sophistication and approaches. This review, provides researchers, construction professionals, and politicians with a better understanding of the advances made to effectively design buildings retrofitting measures, promote energy conservation and the assessment of the building stock for the development of policies. The review shows that many tools have the potential of joining their capabilities, which can produce many opportunities for innovation in the retrofitting area.

Keywords: Retrofitting evaluation tools, building certification, building energy evaluation tool

Introduction

It is well known that the building sector has a great share of responsibility on global energy consumption, which is expected to grow in the next decades (Pacheco-Torgal, 2017). Even more it has been reported that consumption of buildings is exceeding the other major sectors like industry and transportation (Pérez-Lombard, Ortiz, & Pout, 2008). Therefore, building renovation is a the key point to reduce global energy uses and CO2 emissions (Ürge-Vorsatz, Harvey, Mirasgedis, & Levine, 2007), as building for better indoor quality and lower fuel consumption reduces carbon dioxide emissions and pollutes less the environment (Basarir, Diri, & Diri, 2012). Reason why retrofitting existing buildings

represents one of the major challenges for the transition to a low carbon society (Christensen, Gram-Hanssen, de Best-Waldhober, & Adjei, 2014). In this context, governments around the world have taken strong measures towards the retrofit of existing buildings in terms of improving energy performance (El-Darwish & Gomaa, 2017), with different approaches, since Retrofitting existing buildings for energy efficiency involves substantial funding and decision-making from a wide range of stakeholders such as landlords, tenants, property managers, developers and local council (Alam et al., 2016). Moreover, there are many Barriers that may prevent renovation (C. Wilson, L. Crane, & Chryssochoidis, 2015), in the case of retrofitting, energy efficiency strategies are mostly not applied due to a lack of certainty about the amount of investment required and the efficiency of the potential energy saving strategies (Basarir et al., 2012). The clearest attempt to address this issue it has been done by the European Union where a certification system has been put in place for existing buildings. The certification was designed to provide information to building owners and tenants on the energy performance of their buildings, heating and air-conditioning systems, and on effective ways to improve these through building renovation works (European Commission, 2016). The certificate provides as well expected saving and the cost involved if the measures are carry out. However, the results from that evaluation shows that that tool need several improvements in order to be uses effectively as a trigger for renovation purposes (European Commission, 2016) (Geissler & Altmann, 2015). As it was stated above, renovating existing building stock is a relevant issue, however, before taking actions, there is a need to direct efforts in the right direction and to do so, the main actors must be identified as well as their specific needs in terms of knowledge, tools and information. In practice the decision to retrofit a building is, in most cases, up to the building owners, who need to understand clearly the benefits on the short and long term, have confidence on the projections of savings and indoor quality conditions and have a clear estimation of the costs of the retrofitting.

According to the result from IBROAD survey, applied in three European countries (Volt, Fabbri, & Groote, 2018), **homeowners**' motivations to invest in energy renovation are centered around comfort and energy use/cost. Being the upgrade of their home to a warmer and more comfortable house by large the most common aspiration. This report, also adds that the most wanted information from homeowners is, estimated costs of each renovation step, expected benefits in terms of reduced heating/bills and technical information to help them avoid mistakes. When it comes to performing the renovation project, most of the homeowners will hire a contractor to do the job. However, a significant share of the interviewers claim that some of task of the renovation are performed by themselves. This is coherent with the case of other countries like Norway where homeowners renovate their home mostly because they enjoy working in their home. On the other hand, The Building Performance Institute of Europe (BPIE) survey [6] identified that there are many barriers related to knowledge and technical expertise within **energy consultants, certifiers and architects**. They also have different levels of knowledge and participate differently in a renovation process. Energy consultants are closer to auditing, although they are oftentimes too expensive to hire for a single house residential retrofitting. In general, most consultants will use tools that are more sophisticated than the ones that a regular architect would use. It is relevant to note that not all architects are interested in the energy performance of buildings, nor have the competence to develop successful measures to improve the energy performance of buildings, therefore special requirements on information and communication are needed (Bittner & Lechner, 2004). In general, architects tend to look for a general understanding of the problem to explore acceptable solutions and are prone to propose the design solutions on the basis of experiential knowledge (Cross, 2006). To add up, construction actors involved in renovation projects, specially in residential buildings, lack of knowledge of the s available option to upgrade buildings and issues associated with the implementation of specific retrofit. Regarding the accuracy of the measured energy performance of an existing dwelling, data collected by a consultant through building inspection has a very strong impact on the outcome of the calculation of the Energy Performance Indicator and therefore the retrofitting measures are more effective. For a reliable data basis and the comparability of the collected data, consultants have to be aware of what the sensible points are, through home Inspection (Bittner & Lechner, 2004).

The scale of information needed by **Policies makers** and investors is much greater, since they must evaluate it at national, communal or district scale. In general, the studies on this area deal with identifying quarters or building typologies in need of retrofitting considering, age, state of conservation, energy consumption and ownership among other indicators. This allows to find segments with a high propensity to renovate or with needs or vulnerabilities. Some of the policies in place at the time include evaluating properties that are put in the market (new or used) through energy performance certificates, and giving financial incentives or support towards old 'hard-to-treat' properties or low income neighborhoods. Other examples of policies include comparative billing to increase the 'observability' of household energy consumption, hireling energy service companies to manage the 'complexity' and cognitive burden of renovation decisions, and neighborhood and community programs, as well as open house schemes, to support social communication on energy efficiency.

In sum, although the building construction sector and stakeholders acknowledge the need for integrated solutions for maintenance and renovation, there is lack of specialized knowledge on how and when to successfully maintain, manage, adapt, transform and redesign (Itard, 2008). Moreover, most crucial decisions happen in the first stages of the design

process; thus, designers need tools that will assist them in creating better and more sustainable refurbishment projects (Konstantinou & Knaack, 2011)

Review of tools for building retrofitting

There have been limited attempts to systematically review available analytical tools for improving energy efficiency in the buildings sector, where most of the existing reviews of tools and methods have a broader scope than energy efficiency in buildings (Petrichenko, Aden, & Tsakiris, 2016). It is worth noting a report from Lawrence Berkeley National Laboratory (LBNL) (Lee, Hong, & Piette, 2014) in 2014, reviewed sixteen existing tools available for retrofitting purposes, targeting small and medium size office and retail buildings for California-specific conditions and it concludes that an easy-to-use, readily accessible retrofit assessment tool is needed to help Small and Medium Building owners to make wise decisions by providing information about energy savings and economic benefits from the investment in energy efficiency retrofits.
The goal of this work is to review the currently available retrofit tools available for homeowners, energy consultants and policymakers, targeting residential buildings. Researchers investigated retrofit tools both in the public domain as well as in the private sector to better understand the diverse approaches currently in use to evaluate retrofit options: specifically, calculation methods, retrofit measures, financial assessment, and policy development.
To map the existing range of tools and to facilitate building energy efficiency improvements, this working paper presents an overview and categorization of current tools, as well as offering a decision tree, illustrating the types of tools policy and project development in the field of energy efficiency in buildings.

Methodology

To prepare the review two main tasks were fulfil, tool selection and categorization. For the selection, fifty tools were studied, being sixteen the application that are included in this research. It has been either identified as relevant due to their contribution to help in the renovation tasks, in designing a different model of evaluation, assist in specific solutions, provide detailed support to key users or deliver information in a different, interactive and influential way. The categorizations were organized into three groups, renovation assessment, financial assessment and transfer of knowledge. Each tool was resume, delivering an introduction of the tool, their feature and the novelty.
Renovation assessment: In this category tools are selected due to their capacity to assist in the evaluation of measures for renovation, either by delivering technical recommendations, energy reduction, design guidelines, comparison of scenarios, etc.
Financial assessment: Tool dedicated to assist in the economical phase of the renovations process are included in this group. Not limited to just the calculation of the savings or finding the cost optimal, also tools that provide costs, tailor approach to evaluate implementation costs or to help investors to find investments opportunities.
Transfer of knowledge: Renovation is not only about defining profitability or accurate renovation measures. It also can be included the transfer of knowledge, either to promote the benefit of renovation or help stakeholder to produce better guidelines, policies or evaluate program, etc.

Results

Renovation assessment requires multiple tasks therefore, to find a tool one size fits all, it may be not the most appropriate solution. Due to this, in the study several tools are presented that can contribute during the renovation assessment, the selection explores different approaches to support the renovation decisions rather to find the most complete tool. The targeted audience; energy consultant, certifier or architect are relevant for the classification, as well as energy performance and life cycle cost assessment. This section presents detailed information from each tool, summarizing how the tool can serve during a renovation process, the scope, features and targeted user. In total, the study examines sixteen selected tools. Table 1 outlines the diverse features of the sixteen tools, including developer, target buildings, user groups, and interface type, calculation methods, and gaps.

Renovation assessment
INSPIRE: Is a software developed within the framework of the international Eracobuild project INSPIRE. The INSPIRE Tool focuses on residential buildings and simple office buildings without cooling needs (Almeida & Ferreira, 2017). It was designed following the principles of ISO 13790 and considering energy performance of building envelope, outdoor climate, target indoor temperature, and internal heat gains.

Features: The tool allows to investigate trade-offs and synergies between different retrofitting measures and to identify strategies aiming at reducing primary energy use and greenhouse gas emissions while being cost-effective. The tool includes a database of empirical techno-economic characteristics s in different categories.
Novelty: The novelty of the tool is to assess relations between GHG emissions or PE use vs. the life cycle costs. Typically, this kind of tools includes only the calculation of GHG emissions and PE use. The tool includes a wide variety of options to be evaluated in terms of GHG emissions and PE use reduction. The strength of the tool is a possibility to compare different renovation packages with reference cases and to build up a renovation strategy with different steps. This enables users with little detail-knowledge to use the tool and to generate (preliminary) results in the first stage of development. All default-values from the database can be overwritten at any time if more accurate values are available. This approach makes the INSPIRE Tool a good choice in any phase of a retrofit project. User: The software was developed as a Microsoft Excel spread-sheet, providing maximal flexibility and a familiar working environment for the user. For easy updating and maximal performance the data is stored in a separate file and accessed by using industry-standard SQL commands (Jakob et al., 2013).
A56opt-tool: This software was developed in the framework of the International Energy Agency's Energy in Buildings and Communities (IEA EBC) program Annex 56: "Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation". The tool aims to support decision making in terms of building renovation (Dalla Mora, Peron, Romagnoni, Almeida, & Ferreira, 2018) allowing to compare and evaluate different packages of renovation measures.
Features: Is a tool for analysis of the cost-effectiveness of energy-related renovation of existing residential buildings and low-tech office buildings (without HVAC systems). The software is on a Microsoft Excel spreadsheet structure, providing maximal flexibility and a familiar working environment for the user. The Excel sheet uses simulation data that comes from other tools related to each renovation scenario under analysis, such as: area of intervention, energy performance (energy needs or use), costs (investment, maintenance, energy) and environmental impact (GWP and / or embodied energy (Almeida & Ferreira, 2017). The main results of different renovation packages are presented in graphs of emissions in relation to the life cycle costs for each renovation package and primary energy use in relation to the life cycle costs of each renovation package (Dalla Mora et al., 2018).
Novelty: A56opt-tool allows performing optimization analysis, providing renovation packages comparing and evaluating them, identifying the cost optimal and the cost-effective solution, using secondary information and simulation data coming from other tools related to each renovation scenario under analysis.

Financial assessment
The Total Concept: Is a method for improving energy performance in existing non-residential buildings with the aim of assuring maximum energy savings in a profitable way by applying a comprehensive approach, accurate investment & return forecasts and close follow-up. (Wahlström, Maripuu, & Abel, 2015)
Features: The tool provides a method based on an action plan comprising a package of measures that fulfils the property owner's profitability requirements. To present the cost-efficiency in a simple-to-understand way, internal rate of return model is used. When forming the action package both the single cost-efficient measures ("low hanging fruits") and the costlier measures are considered. From an economic point of view, the single cost-efficient measures are related to and support the costlier measures. This way of working has shown that total energy savings of up to 50% are possible. The profitability calculations are done with the Total Concept tool, the TotalTool, where the outcomes are illustrated in a simple-to-understand way by using an internal rate of return diagram.
Novelty: The method is based on the same economic conditions, calculating the global cost of a package of measures as the cost-optimal methodology, but the results of the calculations are presented in a different way. It aims at presenting how to go further with more measures carried out and still meet the profitability expectations set by the building owner.
ECC: European Construction Costs, or ECC, is an online platform dedicated to making construction cost data in Europe more accessible to project developers, investors, quantity surveyors, architects and other important stakeholders in the construction industry.
Features: The database provides detailed data of a wide range of European construction costs. It works as an online cost calculator, developed to help improve the quality, reliability and effectiveness of construction cost management. it was founded by IGG Bointon de Groot and Rider Levett Bucknall, in collaboration with the RLB Euro Alliance.
Novelty: EEC is an online European cost database, that opens many opportunities either for construction companies, building projects, but also for economical assessment. Through an official cost data base, economical assessment for renovation can be designed using standardized methods, and policies can benefit from transparent sources of costs. This feature has not been exploded by EEC, but could be used for these purposes.
Easykenak: his tool has been developed by a group of Greek energy auditors according to Greek standards and regulations for Energy Efficiency of Buildings. The application is targeted to energy efficiency professionals who are certified by the Greek Ministry of Environment as Energy Auditors.

Feature: Easykenak is a web-based application which minimizes the time required for the Energy Performance certification (EPC). The online tool, sets four simple steps to produce an EPC, saving time and being tailored to the needs of the certifiers day-to-day work. The tool includes a feature to quickly draw the building calculating automatically the envelope data, it also includes an algorithm that helps the auditor calculate surfaces of the envelope (opaque and transparent) as well as U values. Once all the data has been submitted, it is processed and is then possible to calculate the Energy Efficiency of the Building. The energy performance results are displayed to the certifier who has the option to select from a wide assortment of energy efficiency measures and re-calculate the energy performance, adding up to 3 energy efficiency scenarios. The certificate can be downloaded in an xml file.
Novelty: Is a private initiative to improve and facilitate the process for certifiers to calculate and obtained an EPC under the Greek regulation.
ENERPAT: (Energy Planning Assessment Tool), has been developed by the research group ARC Engineering and Architecture La Salle, within the framework of the ENERSI project funded by the "State Research, Development and Innovation Program Oriented to the Challenges of Society " (RTC-2014-2676-3), carried out in the period 2014-2017.
Features: it is an application that enables professionals in the building sector (architects, urban planners, builders, technicians and municipal managers) to assess the state of the residential building stock and define rehabilitation strategies to improve the energy efficiency of the buildings. The application integrates the data obtained from the Energy Performance Certificates provided by the Catalan Institute of Energy (ICAEN), the cadaster and the census sections, together with geographic information. The rehabilitation measures are based on the ICAEN simulation tool and the “Long-term strategy for energy rehabilitation in the building sector in Spain” (ERESEE 2014).
Novelty: The online tool allows to visualize EPC label of buildings in selected cities, estimating the improvement that could be obtained if renovation take place in a certain percentage of building by each category, numbering the measures for each group, this included cost, energy savings and return of the investment.
EPIQR Software: Development of a European methodology and software for building audits of apartment buildings and techno economic assessment of refurbishment actions for improved energy performance and indoor environmental quality.
Features: During the building audit, the user specifies the elements/types for a given building and determines their stage of deterioration by selecting a deterioration code “a, b, c, or d” that best fits the observed state of each element/type. Before making the selection, the user can review the corresponding text with a detailed description and several photos that illustrate the four possible deterioration stages. A total of about 500 photos and sketches support the user to select the appropriate deterioration code. The software (Flourentzos, Droutsa, Wittsen 2000) contains for each building element a description of usual deterioration and corresponding refurbishment work including costs, potential upgrading work as well as related national standards and guidelines.
Novelty: decision process of whether and how maintenance and refurbishment should be done. EPIQR uses a systematic diagnosis formalism to determine the current state of deterioration of each element and its impact on energy consumption and indoor environment quality. It also calculates the global refurbishment cost and the energy requirement of the new situation. A cost analysis is possible using the EPIQR cost database with more than 900 detailed refurbishments.

Transfer of knowledge

EHED: A user-friendly software, named EHeD, has been developed to predict the airtightness of Chilean homes.
Features: The software is aimed at non-expert users in the sustainability area, to evaluate the expected behavior of the home, with different scenarios and options which allow orientating the design stage. The software allows to predict the performance of homes under the building regulation, targeting designers, builders or owners to make decisions when making changes to improve airtightness. The calculation model was obtained by analyzing the airtightness of homes in Chile, supported by laboratory and onsite measurements of the home’s components (González Cáceres, Recart, Espinoza, & Bobadilla, 2016).
Novelty: The software could be uses to retrofit existing dwelling base on the expected improvement on airtightness reducing the energy need for heating.
EnergySavingCheck 3.0: is an integrated energy advising tool for homeowners and tenants. It is user-friendly and provides valuable information on the household’s energy and water consumption. It was first introduced by Caritasverband Frankfurt e.V, Germany for the EU-funded project ACHIEVE and it is based on the calculation tool of the Cariteam Energiesparservice.
Features: The software is based on an Excel sheet. It requires significant information as inputs, such as data on energy and water use and costs (from bills), electricity using devices (lightning, cooking, washing, entertainment, cooling, heating etc.), state of the building (heating system, insulation, windows, the position of flat, etc.). After the estimation of current energy and water consumption, the end user can calculate the energy and water savings and take the appropriate steps for reducing energy and water use. Also, the relevant carbon dioxide footprint can be calculated.

Novelty: It can be used in the residential sector, but it targets energy poor households, advising residential buildings that cannot afford their energy/electricity bill and/or keep their flat/house adequately warm at reasonable cost.
eeMeasure: is a web based software developed for the European Commission, which enables social housing organizations and municipalities to quickly evaluate their energy policies.
Features: It allows for a harmonized way of recording and calculating energy savings of projects funded by the Information and Communications Technology Policy Support Program (ICT PSP, through a consistent methodology. The software tool is designed to facilitate the evaluation of all kinds of energy saving effects produced by a variety of ICT-based solutions, including behavioral changes and improved public awareness. The aim of ICT PSP projects is to demonstrate the energy efficiency benefits ICT can bring to building owners and their inhabitants. ICT PSP projects currently include approximately 10,000 social dwellings and 30 public buildings (hospitals, schools, etc.)
Novelty: It helps policy-makers to produce a better quantitative analysis on the energy savings potential of ICT based solutions in residential and non-residential buildings.
The HERON-DST: An innovative, friendly to the end user, software developed by KEPA in the frame of the HERON project (H2020, Grant AgreemENT. No. 649690), it aids policy makers and market stakeholders in their energy efficiency policy making for buildings and transport.
Feature: The HERON-DST stands for Decision Support Tool, it provides a user-friendly software that facilitates the selection of the optimum combination of technologies and practices minimizing the negative impact of end-users behavior in the implementation of energy efficiency scenarios to be used by policy makers. One of the reasons for seeking an approach that quantifies the barrier impact is the need to have numerical inputs for the forward-looking energy efficiency modelling (National & Kapodistrian University of Athens-Energy Policy and Development Centre, 2016).
Novelty: The HERON–DST allows to calculate the impact factors of behavioral barriers on the inputs drivers or alternatively on final users.
TABULA: Developed based on the common DATAMINE data structure and the experiences of typological classification. The objective of the project was to create a harmonized model for European building typologies, in particular, residential buildings. The set of typologies represents different construction periods and building sizes. The results of the building typologies are compiled and presented in the TABULA web tool (Ballarini, Corgnati, & Corrado, 2014).
Feature: On that basis, each participating country developed a national “building typology”, that is a set of modeled reference buildings (named “building types” in the project), each of them with its specific energy related properties. The building types were used by each country to display energy consumptions and to assess potential energy savings achievable through retrofitting actions tackled to the building envelope, space heating and domestic hot water systems. In the project, two levels of retrofit actions were defined: “standard” through the implementation of measures commonly applied within the country and “advanced” through measures that reflect the use of the best available technologies (Loga & Diefenbach, 2010).
Novelty: The online tool provides data to analyze the existing building stock by typology, construction year, materiality etc. the project has been used for policy making, research projects related to existing building renovation.
ENERFUND: is a European project aiming to develop and promote a tool for stakeholders to make intelligent decisions on energy renovation strategies. The tool targets local authorities, financial institutions and ESCOs, as an evaluation tool before examining in more depth the feasibility or usefulness of deep energy renovation of commercial and other buildings.
Feature: The website tool rates and scores deep renovation opportunities – like a credit score used by banks to rate clients. The tool is based on a set of parameters such as Energy Performance Certificates (EPCs), number of certified installers, governmental schemes running, etc. By providing a rating for deep renovation opportunities, energy services or product companies can identify customer segments based on their needs, environmental department heads can assess and compare buildings when prioritizing deep renovation and deciding on fund allocation and financial institutions can provide targeted loans for building retrofits. ENERFUND is a tool that enhances public awareness in building retrofit potential.
Novelty: An interactive map of Europe where the user can visualize the energy ratings of buildings and narrow them down by applying filters, where the data can be easily analyzed. The interface consists of multiple layers, which use a range of different mapping technologies, through the large amount of data and visual capabilities, the app can be used by several stakeholders.
Em Build Navigator: is a project financed under the Horizon2020 Programme which developed a comprehensive online guidance tool providing practitioners in Europe with practical instructions on how to design and implement a renovation strategy for buildings. The EmBuild Navigator is structured around three main pillars: Plan, Invest, Benefits, which all are all aimed to provide local municipalities with the right toolbox to construct a successful strategy for the renovation of public buildings.
Features: The Navigator starts with the planning: the value of a strategy consists not only in the renovation strategy itself but also in the process behind its development. The available tools include spreadsheets, templates and analysis

on the exploration of the regulatory framework, the technical solutions, the barriers, and a national renovation strategy template. EmBuild partners provided a set of best-practice examples and recommendations on how to plan and direct interventions on public buildings and private housing and attract investment. The Navigator provides local authorities with a reference to address benefits of renovation measures to target groups, as well as to strengthen motivational aspects in building renovation programs and illustrate that renovation is not only a matter of energy savings.

Novelty: With the use of EmBuild material, municipalities can use a comprehensive approach to plan, invest and implement wider benefits in their decision-making process and in the necessary reporting and evaluation schemes for deep renovation measures. The tool will raise the knowledge and awareness amongst local stakeholders on the wider benefits of renovation, such as comfort, air quality and local jobs.

EDGE: is an online building design software, a certification system, and a global green standard for more than 140 countries. The platform is intended for anyone who is interested in the design of a green building, whether an architect, engineer, developer or building owner (International Finance Corporation (IFC), 2018).

Features: EDGE is intended to meet the demand for a quick, easy and affordable online application that can be used to plan and assess the design of resource efficiency to scale up green building growth. The complexity of the underlying methodology lies beneath the application's interface so that industry professionals can easily determine resource efficiency and associated cost savings without the necessity of hiring energy specialists or purchasing additional modelling software. EDGE incorporates available embodied energy data of construction materials from around the world. The major point of reference for the data, which is also referred to as Materials Life Cycle Analysis, is the Inventory of Carbon and Energy (ICE) developed by the University of Bath.

Novelty: EDGE utilizes thermal calculations to determine the building's overall energy demand, including requirements for heating, ventilation and air-conditioning, as well as domestic hot water, lighting demands and plug loads. EDGE also estimates water use and the embodied energy of materials used in constructing the building, to create a comprehensive analysis of projected resource usage.

EnergimerkeKalkulator: is a Norwegian website tool used to generate EPC based on a self-assessment method, with this building owners can produce their own certificate without spending money on a certifier.

Features: For the evaluation of existing buildings there are two options, where the first allows the homeowner (non-expert) to generate their own certificate, this option requires little technical information about the building, such as age of the construction, floor area, and energy sources. Many aspects are standardized, such as the building shape, windows and doors area, floor to ceiling height, etc. The second option requires information that is more detailed, High-level knowledge is not needed, but this option is more time consuming than the first one, especially the description of the envelope, where customized U-values can be added.

Novelty: This system intends to encourage the owners to be more involved and to stimulate their interest in energy efficiency (Isachsen, Rode, & Grini, 2011).

Discussion and Conclusions

An extensive review of 16 tools used for renovation purposes was selected and presented in brief but in a comprehensive way. The tools were grouped by their target user, renovation assessment, dissemination and certification of existing homes. The results of the reviews show that innovation in tool design is relevant prove of this and the number of tools developed under research projects with organizational funding ads to this statement. It is clear that renovation of existing buildings is a priority issue, where different sectors have space to promote new ideas and contribute in the development of solutions, from the public or commercial sector. Another remark is the wide spectrum of tasks and approaches that these tools have implemented, including fuel poverty, water savings, airtightness improvements, policy evaluation etc. As well as the users that are target, among other homeowners, municipalities, investor and policy-makers. Despite that many of the tools are no longer available; their contribution may be used for developing new tools based on their scheme, upgrading their capabilities with the current technology. Equally important is the fact that no tool can do it all, and online tools are becoming more popular an accessible for the users, the promotion of these software is another key factor to trigger their uses and the renovations of the existing building stock. From this review, it is clear therefore that there is no common agreement on the scope, indicators and calculation methods for the evaluation of retrofitting measures. Differences in the approach to retrofitting are dependent on the scope of the development agency and on the country framework on climate change mitigation. The results of this review are the base for the development of a new tool targeting renovations in residential buildings, where the presented tools may be uses as part of a methodology to assess renovation measures under the EU Energy Performance Building Directive (EPBD).

Table 1: directory of studied tools

Tool	Target audience	Main features	System

INSPIRE	Energy manager, architects and engineers	Cost optimal and cost effective measures	Spreadsheets
A56opt-tool	Energy manager, architects and engineers	evaluating different packages of renovation measures	Spreadsheets
The Total Concept	Energy manager, architects and engineers	Method to calculate profitable renovation measures	Computer program
ECC	Auditor, architects and engineers	online European cost database	On-line
Easykenak	Certifiers	Energy Performance Certificate	On-line
ENERPAT	Auditor, architects and engineers	Building stock analysis and provided renovation measures	On-line
EPIQR	Auditor, architects and engineers	Assist during building audits	Computer program
EHED	Home owner	estimated airtightness savings	Computer program
EnergySavingCheck 3.0	Home owner and policy maker	water consumption reduction	Spreadsheets
eeMeasure	policy-makers	evaluation of all kinds of energy saving	On-line
HERON-DST	Policy makers and market stakeholders	minimize the impact of end-users' behavior in the implementation of energy efficiency	Computer program
TABULA	Policy-maker and researchers	Typological classification	On-line
ENERFUND	Authorities, financial institutions and ESCOs	Rates and scores deep renovation opportunities	On-line
Em Build Navigator	Municipalities	evaluation schemes for deep renovation measures	Spreadsheets
EDGE	professionals in the building sector	Certification	On-line
EnergimerkeKalkulator	Home owners and Certifiers	Energy Performance Certificate	On-line

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