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Guidelines, barriers and strategies for energy and water retrofits of public buildings

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A B S T R A C T

Government departments and their agencies occupy a significant portion of building stock, whose annual water and energy costs are substantial. Although it has been demonstrated that retrofitting public buildings can lead to drastic reductions in water and energy consumption with rapid payback periods, in most countries the retrofitting rate is very low. In addition, the focus of retrofit projects is often solely on energy, while water conservation and the water-energy nexus are typically neglected. To improve the current lackluster retrofit rates, the key challenges and potential coping strategies must be identified and retrofit program implementation frameworks developed. This research study adopted a mixed methods approach including scenario modelling and stakeholder workshops and interviews, to achieve such objectives. The comprehensive review identified retrofit project financing and procurement impediments to be the greatest deterrent, although other factors such as education and awareness-raising, which are typically overlooked, were also recognized as being critical. Interviews with stakeholders revealed that governments' willingness to introduce a retrofit program and related supporting mechanisms is also a major barrier to public building retrofitting. Coping strategies for achieving accelerated implementation of retrofit projects were identified as being the introduction of project facilitation teams, revolving loan funding, performance contracting, to name a few. Once such barriers and strategies were acknowledged and refined through stakeholders' consultation, scenario modelling was conducted in order to quantify the benefits of a proposed widespread retrofit program. Modelling results demonstrated a potential five-fold return of capital investment for a nationwide Australian hospital building energy and water retrofit program if the recommended financial and procurement mechanisms were put in place. Such results and final project outcomes were presented to key-stakeholders in order to incentivise decision-makers to implement some of the proposed strategies and finally boost the building retrofitting sector.

1. Introduction

Water and energy efficiency are critical for sustainable development and climate change mitigation, and buildings have a central role to play in such efforts. Buildings are one of the largest users of energy, accounting for 32% of total global final energy use and 19% of total energy-related greenhouse gas (GHG) emissions (Lucon et al., 2014). Many of these existing structures were built before the establishment of appropriate efficiency codes, often meaning that they are energy and water inefficient. By 2050, global world building heating and cooling energy use could be reduced by about 46% as compared to 2005 values (Ürge-Vorsatz et al., 2012) through incorporating today's best practices in building design, construction, and operation, as well as accelerated state-of-the-art retrofits, with potential of energy and water consumption reduction of up to 40% through building retrofitting (Beal et al., 2012; Willis et al.,

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List of abbreviations

ACT	Australian Capital Territory
ARID	Accessible, Robust, Integrated, Dynamic
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AUD	Australian Dollar;
BN	Bayesian Network
CO_2-e	Carbon Dioxide equivalent
DSM	Demand Side Management
ECBCS	Energy Conservation in Buildings and Community Systems
EEGO	Energy Efficiency in Government Operation
EEIS	Energy Efficiency Improvement Scheme
EnvUpAgr	Environmental Upgrade Agreement
EPC	Energy Performance Contracting
ESCO	Energy Service Company
ESG	Energy Smart Government
ESS	Energy Saving Scheme
EU	European Union
EUF	Environmental Upgrade Finance
FEMP	Federal Energy Management Program
GBE	Government Building Energy
GGB	Greener Government Building
GHG	Greenhouse Gases
GREP	Government Resource Efficiency Policy
GWh	Gigawatt hour
High impl	High Implementation rate
HVAC	Heating, Ventilation, and Air Conditioning
IEA	International Energy Agency
ICT	Information and Communication Technologies
KPI	Key Performance Indicator
LED	Light-Emitting Diode
M&V	Measurement and Verification
ML	Megalitre
NGO	Non-Governmental Organisation
NSW	New South Wales
QLD	Queensland
REES	Residential Energy Efficiency Scheme
RLF	Revolving Loan Fund
SD	System Dynamics
SEEP	Strategic Energy Efficiency Policy
PF	Project Facilitator
PV	Photovoltaic
US	United States
VEET	Victorian Energy Efficiency Target scheme
WA	Western Australia

2011). However, in most developed countries, more than 98% of the building stock consists of existing buildings, and new construction accounts for only 1–1.5% of total building stock at any time (McAllister and Sweett, 2007). Therefore, retrofitting existing buildings is the key to a sustainable future because the vast majority of the buildings that we currently occupy, and their respective energy and water use profiles, will be with us for the long term.

Like other developed countries, a significant share of Australian existing building stock were built before the introduction of recent efficiency codes, and in the current business as usual scenario, the building sector could potentially account for almost half of Australia's carbon budget by 2050 (ASBEC, 2016). The carbon budget represents the maximum GHG emissions a country can release according to the Paris agreement (United Nations, 2015) to limit the global warming to 2 °C. Therefore, the issue of building retrofitting is also crucial for Australia to help minimise the carbon emissions and associated global warming. Moreover, modelling results showed that retrofitting buildings can potentially deliver a 23% reduction in emissions and AUD$20 billion in financial savings by 2030 in Australia (ASBEC, 2016). Such savings would increase even further if the public health benefits are considered in the analysis, as the link between environmental pollution (e.g. sulphur dioxide and wastewater emissions) and public health is well established (Lu et al., 2017).

Public buildings occupy over a quarter of the national commercial building stock in Australia and the associated energy and water costs are as high as AUD$1 billion per year (ANAO, 2009). The majority of these public buildings (e.g., schools, libraries, hospitals, offices) are existing stock which were designed and constructed with insufficient consideration for energy and water efficiency. In general, it has been assessed that energy efficiency can increase financial performance (Fan et al., 2017). By retrofitting these building stock, the governments can typically reduce energy use and GHG emissions in their buildings by 25% with an annual return on investment of 7–15% (GPG, 2011).

The goal of building retrofits is to reduce the energy and water costs, and GHG emissions, through different methods such as passive approaches (e.g. improved insulation level), replacement of inefficient appliances with efficient ones, and on-site production of renewable energy (Ferreira et al., 2016). A large body of evidence, in the past 30 years or so, has demonstrated that large monetary savings could be achieved with water and energy efficient buildings (Rosenfeld and Hafemeister, 1988). Yet, the potential for the retrofitting industry to become a main driver for water/energy efficient and climate-wise cities, has not been fully realised due to a number of barriers. These retrofit project barriers have been documented in the literature (Bertone et al., 2016c; Ryan and Murray-Leach, 2011) and their impacts analysed in scenario modelling (Liang et al., 2016). In the Australian context for instance, although few policies exist (Dowling et al., 2014), the retrofitting rate is still quite low, and in line with other parts of the world such as the US and EU where the retrofitting rate is about 3% per year (Zhivov, 2013). There have been a few policies attempting to increase government buildings' efficiency in recent times. In 2006, the Energy Efficiency in Government Operation (EEGO) policy was introduced to improve the energy performance of the public building stock in Australia (EEGO, 2007). However, due to the lack of a comprehensive implementation strategy, the expected policy outcome was not achieved. A number of states in Australia have gained some progress in this regard through introducing their own retrofitting policies, targets and guidelines, such as the Energy Saving Scheme (ESS) and Government Resource Efficiency Policy (GREP) in New South Wales, Victorian Energy Efficiency Target (VEET), Greener Government Building (GGB) program in Victoria, Retailer Energy Efficiency Scheme (REES) and Government Building Energy Strategy (GBE Strategy) in South Australia, and Energy Efficiency Improvement Scheme (EEIS) in ACT. Since 2009, the GGB programme in Victoria led to AUD$134 million invested in water and energy efficiency upgrades (Bertone et al., 2016c; Department of Treasury and Finance, 2016). The GREP, which was introduced in 2014, also resulted in an increase in the public building retrofitting rate in NSW. However, these are localised examples and a clear national policy is not present; also, other states such as Queensland, Western Australia and Northern Territory currently lack policies and guidelines to retrofit their public building stock. In addition, often energy and water efficiency are considered separately, with water efficiency and the water-energy nexus often overlooked and underestimated (Bertone et al., 2016c; GHD, 2006). Internationally, a number of successful and unsuccessful policy examples can help identify barriers and copying strategies for the retrofitting sector on a general scale; however, it is not automatic that a series of recommendations would flawlessly work in a specific context or country.

As a result, the objectives of this research project were:

- To identify barriers and coping strategies for the retrofitting industry on a general, international level.
- To quantify, through prediction modelling, the potential monetary/environmental benefits of implementing a number of best-practice actions in the Australian context.
- To develop comprehensive retrofitting guidelines and an implementation strategy based on the research results and stakeholders' feedback and input.

To achieve these objectives, a hybrid mixed-method approach has been adopted in this research. The existing studies in this area either only focused on doing a comprehensive review of barriers and opportunities of retrofitting (e.g. Ma et al. (2012); Tanaka (2011)) or only carried out scenario modelling to show the potential cost, energy and water savings and reduction of GHG emission through retrofitting (e.g. Kenway et al. (2013); Walter and Sohn (2016)). The adopted approach in this study combined the evidence from past examples and research and the results from the proposed modelling studies. Moreover, practical expertise was drawn from stakeholder engagement employed throughout the research process in order to refine and validate project outputs. Such methodology, in combination with the deployment of a hybrid modelling approach, is novel in the context of building efficiency upgrades.

Section 2 presents the methodology deployed to accomplish the research objectives and the results are discussed in Section 3. The conclusions and implications of the study are presented in Section 4. Fig. 1 schematically represents the main structure of this paper.

2. Methods

Fig. 2 illustrates the main research components and activities undertaken in this project. The components are described in more detail in the following subsections. The first step consists of a comprehensive review of relevant literature, including national and international guidelines as well as previous studies identifying potential impediments and opportunities. Based on this, a comprehensive list of barriers and potential coping strategies to boost the retrofitting industry for public buildings in Australia was prepared. Through a cyclic action research feedback process, this list was refined and validated by the relevant government and industry stakeholders participating in the project. Based on such feedback and collected data, two prediction models were developed in order to validate the findings and quantify the costs and benefits of the proposed public retrofit implementation strategies (e.g. designed regulatory and financial mechanisms) for the Australian context. Two final stakeholder interaction workshops served to derive a final set of recommendations and to refine and endorse a developed set of guidelines.

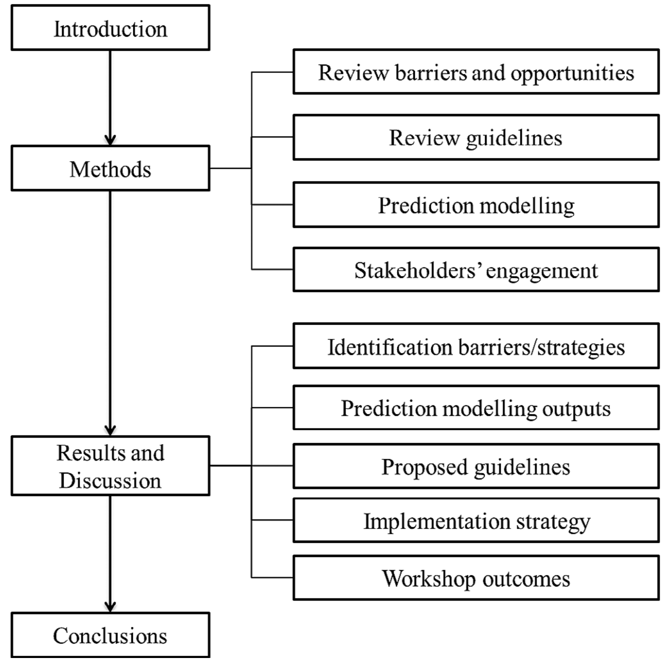

Fig. 1. Schematic overview of paper structure.

2.1. Literature review: barriers and opportunities

A review of relevant academic studies and industry reports, at an international level, was conducted. Preliminary results were described in Bertone et al. (2016c). Based on the research focus outlined in the preceding sections, keywords were selected and primary searches were conducted though Scopus and Google Scholar. The resulting list was then also integrated with a number of reports from international and Australian agencies as well as consultancy and industry reports. Given the topic of this research project, grey literature (e.g. industry and government reports) was considered fundamental for this particular study.

2.2. Review of national and international guidelines and schemes

A number of national and international government building retrofitting guidelines were analysed in terms of retrofitting steps, relevant policies and targets, implementation methods and current progress. The necessary data for the current research was collected from the government websites, relevant government reports and through direct communication and interviews with relevant government personnel. Based on the review and lessons learnt from different retrofitting programs, and stakeholders' consultation, a set of public building retrofitting guidelines was developed. The lessons learnt through the interviews and stakeholders' consultations were also used to develop an effective implementation strategy for government building retrofitting programs.

2.3. Prediction modelling

After having identified international best practices for different aspects of the retrofitting sector (e.g. financial, procurement), a combined hybrid Bayesian Networks-System Dynamics model was developed as discussed in Bertone et al. (2017). The goal of the BN-SD model was to predict the Australian public building retrofitting rate, and associated costs and benefits, for a combination of proposed strategic recommendations such as innovative financing

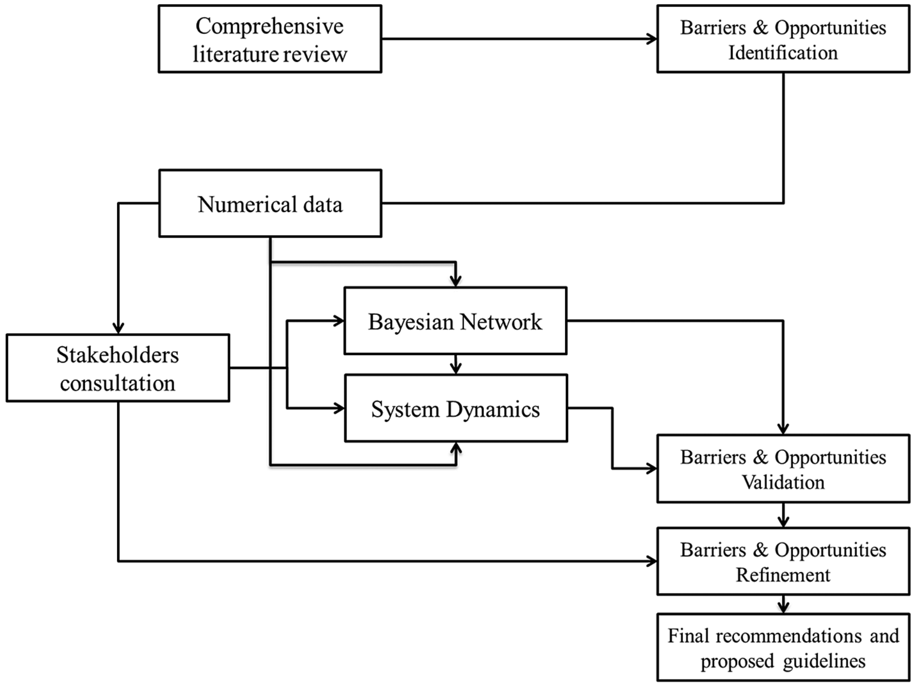

Fig. 2. Research components flow chart.

arrangements and supportive regulatory mechanisms.

Bayesian Networks (BN) represent a probabilistic modelling approach which can deal well with uncertainty and can incorporate stakeholders' inputs (Fenton and Neil, 2008), while Systems Dynamics (SD) can be used to improve policy and decision-making (Sterman, 2000). Both of these techniques have been used extensively in the water and energy sectors (Bertone et al., 2016a; Ford, 1997; Sahin et al., 2015). A combined BN-SD approach has been previously proposed by some of the authors within the ARID (Accessible, Robust, Integrated, Dynamic) framework methodology (Bertone et al., 2016b) and has been successfully applied in water-related research projects (Bertone et al., 2015, 2016a). The benefits of combining these two diverse modelling approaches is that they offer complementary characteristics that overcome each other's limitations. Specifically, BN allows for modelling systems with uncertain, missing, and multidisciplinary data (Uusitalo, 2007). Additionally, BN processing time is considerably shorter than process-based models (Beaudequin et al., 2016; Uusitalo, 2007), and is considered more transparent than data-driven, “black box” approaches, such as artificial neural networks (Chen and Pollino, 2012). However, BN cannot easily, if not at all, account for continuous variables, time, or feedback loops (Uusitalo, 2007), which would be beneficial in order to obtain a better understanding of certain systems to be modelled (Sahin et al., 2015). A limitation of SD is that it is reliant on extensive continuous datasets that are discrete and quantitative. By integrating BN with SD, it is possible to conduct temporal analysis and account for feedback loops and time lags. Such integration can be done by either directly using some of the BN output nodes' information as an input into the SD model, such as described in this study, or by modifying SD to make them “fuzzy SD” (Nasirzadeh et al., 2008; Tessem and Davidsen, 1994).

This research approach was also deemed appropriate for this study, since: (1) the system is highly uncertain, as it has been documented that qualitative socio-economic factors significantly influence the diffusion potential of retrofitting technologies (Yang and Zhang, 2016); (2) a number of variables would not have available numerical data, and thus through the BN this can be replaced with experts' judgement, and (3) SD allows the user to more realistically model the implementation of any proposed strategies by taking into account a range of complex interdependent factors. In addition, a participatory approach, in which the relevant stakeholders were engaged in some of the modelling activities (Hare, 2011), such as data collection and model validation, was adopted in this study. This approach also facilitates the inclusion of all the relevant key parameters when modelling the system; thus ensuring a thorough understanding of the system being modelled (Vennix et al., 1997).

The first critical step was the collection of data about the public building stock; this includes general information (e.g. size, location), as well as water and energy consumption. This information was collected though a number of publicly available sources including reports and websites (Bertone et al., 2017).

Next, a BN model was developed in order to quantify how the retrofitting rate would change in different financial and procurement scenarios, and by considering different Australian locations and retrofit options such as solar photovoltaic (PV) panels, taps aerators, LED lights; with associated costs and benefits. PV panels represent a retrofit option related to the production of renewable energy and reduction of the non-renewable energy use component, while aerators and LED lightning represent water and energy efficiency-related retrofit solutions. The model incorporates technical and engineering calculations (e.g. amount of electricity produced by n PV panels in a certain location) with more qualitative outputs (e.g. financial attractiveness given certain background conditions) which were estimated based on stakeholders' opinions and input. These were collected during a number of workshops conducted in different Australian states during the course of the research project. The model was calibrated and validated by comparing the outputs of specific scenarios with available retrofitting rates in certain parts of Australia, such as in Melbourne with the “1200 Buildings” initiative (Bertone et al., 2017), and by running a sensitivity analysis to test the impact of some key variables on the overall system, as well as based on experts' evaluation.

Finally, the best financial scenario estimated by the BN was tested by developing a dedicated SD, which was used to optimize the features of such financial mechanism (e.g. loan duration, interest rates, dedicated budget) and predict monetary and environmental benefits of such a scheme being in place in Australia to boost the retrofitting sector.

2.4. Stakeholders' engagement and final workshops

Relevant stakeholders were engaged throughout the course of this project. Experts consulted included champions from the industry sectors as well as from several Australian state governments. Such involvement was conducted through face-to-face meetings and phone calls, as well as (mainly) through a number of workshops and meetings; specifically, two in Brisbane, one in Melbourne, and two in Perth. These were useful to discuss progress and obtain feedback. It was also critical for the prediction models' development (i.e. provision of qualitative expert input wherever numerical data were unavailable). Fig. 2 explains the different steps involved in this project and how stakeholders were a vital part of it and were engaged from beginning to end.

Importantly, two final workshops were conducted in Queensland and Western Australia with participants from senior management roles across various departments. These were crucial in order to validate the findings for specific regional/state contexts. The number of participants was 15 for the Queensland workshop and 29 for the Western Australia workshop. The workshops started with a half-hour presentation covering the study findings, including the review of national and international retrofitting guidelines and best practices, barriers, and coping strategies. This presentation was then followed by a one and a half hour interactive discussion that sought to determine the most significant barriers and suitable coping strategies for each of the identified key-components and factors.

3. Results and discussion

3.1. Identification of different key components and main barriers/opportunities

A preliminary but comprehensive analysis of main barriers and coping strategies for the retrofitting industry was presented in Bertone et al. (2016c); those outcomes provided the foundations for further analysis and refinement based on further research and stakeholders' feedback, as summarized below.

The first critical conclusion, based on the review of successful and unsuccessful examples worldwide, is the clear requirement for an integrated approach that values all the different key-components of a retrofit project. These components extend beyond the simple retrofit installation, and include a number of pre- and post-retrofit activities, both at a national strategy, and individual building levels. The identified five key-components are:

1 Building efficiency assessment
2 Selection of best retrofit option
3 Procurement
4 Financing
5 Post-retrofit measurement and verification (M&V)

Fig. 3 symbolically represents a successful retrofit project as a bridge, where each pillar is one of the aforementioned components; if one wants to cross from one side (energy and water inefficient building) to the other (energy and water efficient building), all of these pillars must be solid and well-constructed. If one of them is missing, it would be very difficult to successfully complete a building retrofit project. Based on our findings, this is the main reason why the retrofitting rate around the world is very low: most of the time, at least one of these components/pillars is either missing or not strong and specific enough.

The following sections briefly describe each of these pillars and provide a number of Australian or international examples. For each step, a number of barriers and coping strategies were identified and discussed during the project workshops with key government stakeholders.

3.1.1. Efficiency assessment

Assessing the energy and water efficiency of an existing building is an intricate task, as it requires both an accurate and reliable monitoring of the building consumption (i.e. monitoring and auditing), as well as reference values once the consumption is assessed (i.e. benchmarking and certification schemes).

An efficient metering policy would be the first step towards a proper national-level public buildings efficiency assessment. If smart meters were used, they could be linked to end-use disaggregation algorithms (Nguyen et al., 2015) able to quickly identify the building areas/devices responsible for the highest water/energy consumption, and in turn highlight the most-effective retrofit options. In addition, if energy/water data for several buildings is collected, this would help with benchmarking and designing national energy/water efficiency policies. As an example, in Denmark a mandatory certification scheme led to a large amount of collected data, which were used for a more evidence-based policy making (IEA, 2010). However, in Australia there is no general mandatory metering; the Australian Governments currently only recommend the use of electricity smart meters (DIS, 2015), while for water there is quite limited metering at all, despite leakages losses commonly reaching 30% of the total consumption (Britton et al., 2013). Although in some states there are regulations (e.g. Queensland Development Code MP 4.1- Sustainable Buildings, 2010) forcing the use of electricity sub-meters, this is valid for specific buildings' categories only (e.g. offices, multi-unit residential) and it solely applies to new buildings (QDHPW, 2013). Regarding auditing, in Australia and New Zealand there are three levels of energy audits of increasing complexity (SA, 2000), but no regulation on which level is required based on the project (Ma et al., 2012). Additionally, there are no standards for water audits.

Focusing on benchmarking, there are several examples of certification schemes worldwide, both mandatory and voluntary. The review shows how both are useful, but voluntary schemes are less effective since, although the owner of an efficient building might have a benefit in obtaining a positive rate (i.e. marketing strategy, public recognition), owners of poorly performed buildings would not have interest or a benefit in investing time and money to eventually obtain a negative certification (IEA, 2010). The issue with mandating a certification scheme is related to the metering barrier: they are usually expensive to undertake, and there is a need for baseline data (to be collected through large scale metering programs) for an appropriate and meaningful benchmarking.

3.1.2. Selection of best retrofit option

Hundreds of energy and water efficiency upgrade options exist, and therefore identifying the most suitable option for a specific building can be quite complex. Often, the "low-hanging fruit" options (e.g. LED lights, window sealing, tap aerators) represent simple, relatively inexpensive, and quite effective solutions, with potentially a short payback period and easy installation. However, for deeper retrofits (e.g. HVAC systems), proper monitoring and auditing activities are necessary to ensure the best upgrade option is found. It must be mentioned that there would be other demand side management (DSM) solutions, other than energy/water

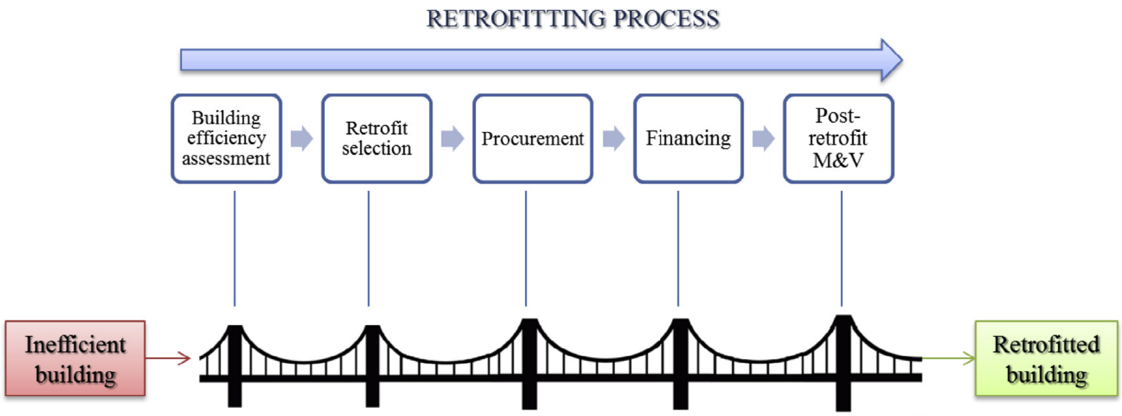

Fig. 3. The five key pillars of a successful building retrofit project.

efficiency or on-site renewable energy generation measures, which would allow for reduced consumption. Managing demand is as important as increasing efficiency, in order to avoid the 'rebound effect' (Copiello, 2017). Some of the DSM options include smart dynamic pricing (Palensky and Dietrich, 2011; Sahin et al., 2017), automated demand response and demand shifting over daily forecast price cycles (Amini et al., 2015), distributed spinning reserve (Palensky and Dietrich, 2011), and supply function bidding mechanism algorithms (e.g. Kamyab et al. (2016)). Although in recent years improved computational modelling capabilities have allowed for optimisation and forecasting algorithms to be more easily developed, many ICT challenges still exist for DSM (Palensky and Dietrich, 2011) and several of the above options rely on the presence of smart meters.

An issue with ranking different options is the need of accounting for co-benefits such as increased tenants' productivity, reduced carbon emissions, and increased property value, which often are difficult to quantify in monetary terms (Bertone et al., 2016c). Adding to the complexity, there are a number of uncertainties (e.g. future energy/water price, climate change, equipment performance), which increase the risk for the building owner of not achieving the savings promised by the contractor, and thus potentially discourage the implementation of such deep retrofits (Ma et al., 2012). In order to address this issue, innovative procurement models are needed to help transfer such risks to the contractor, leading to a safer investment for the owner and to a performance-driven system.

3.1.3. Procurement

Traditional procurement methods, in which a building owner seeks a contractor to undertake auditing and then retrofitting activities, proved to be ineffective, since the owner (e.g. government agency) would typically struggle to find funding for the project and thus the latter would not go ahead (Ryan and Murray-Leach, 2011). In addition, even if the funding is secured, often there is no post-retrofit M&V of the predicted savings. Hence, since these are usually higher than the measured ones, the costs and risks for building owners can be too high. An effective procurement option is provided by the "Integrated Services Models", where a qualified service provider (for energy efficiency, called "energy service company" or ESCO) is selected for not only the retrofit installation, but also for pre-retrofit auditing, project proposal, and post-retrofit M&V (Ryan and Murray-Leach, 2011). In case of "Energy Performance Contracting" (EPC), the whole process is performance-driven as the ESCO will not receive the payment upfront, but will get paid through a portion of the achieved energy savings (Tetreault and Regenthal, 2011). In this way, it is important for ESCOs to correctly predict, and monitoring, the savings to achieve positive returns; this also transfers risk away from the owner, who does not require in-depth technical knowledge but will have a fixed price/savings provided by ESCOs for a number of retrofit options. EPC has been widely used in the United States (e.g. Rhoads (2010)), Canada, Germany, Finland, Denmark and in some Australian States.

However, EPC are generally not suitable for small (<$250,000) projects or remote locations, since they are less appealing for ESCOs (Ryan and Murray-Leach, 2011). In addition, studies found that to be successful, an EPC also relies heavily on other factors such as accurate M&V and team leader's and workers' skills and capacity (Xu et al., 2015). Also, developing an EPC project is a lengthy process, and it drives up the project cost as all the risks are shifted to the ESCO. In the case of low-risk projects (e.g. lighting) with higher project value, the use of EPC unnecessarily increases the project cost, time and complexity. In this scenario, a different procurement model, such as 'Design and Install', can be used (Davis et al., 2008). To analyse the risks associated with a project, a multiple criteria analysis can be used, considering project value, project complexity, risk profile, etc., rather than only project value. After the multiple criteria analysis, projects with high-risk rating may be procured via EPC.

3.2. Finance

Ad-hoc financing mechanisms must be accessible to the building owners to avoid the high upfront costs (USDE, 2012b) required for the installation of energy and water efficiency upgrades and smooth such cost over time. Lack of such financing options represent one of the most critical barriers acting against the acceleration of the retrofitting rate of public buildings Another main financial barrier is given by the split incentive issue (Kong et al., 2012): that is, when the building is tenant-occupied, the owner is supposed to pay for an upgrade whose benefits will be enjoyed by the tenants. A number of financial mechanisms used around the world, which can help overcome such barriers, were identified (Bertone et al., 2016c).

- **On-bill financing**: it helps avoid the upfront costs by allowing repayments through the energy/water bills. The repayments are supposed to be lower than the savings thus allowing for immediate positive returns for the owner. They are usually suitable for small projects. The downsides are, for instance, the potential for private lenders to perceive (because of lack of knowledge) the energy efficiency market as high risk; the utilities themselves, in addition, may have no desire of acting as lenders.

Finally, a strong regulatory support is required (Rockfeller and DB, 2012). Regardless, it is widely applied in the US and in some parts of the UK.

- **Environmental Upgrade Finance (EUF)**: through this mechanism a long-term, low interest rates, loan is provided which is paid back through municipal taxes. These can be transferred to the tenants, thus this system helps avoid both upfront costs and split incentive issue (Ernst and Young, 2015). It requires a deep involvement of the local Councils to facilitate the lending process. It has been applied in several Australian cities in New South Wales, South Australia and Victoria.
- **Revolving Loan Fund (RLF)**: this type of loan provides favourable financial terms and helps qualify for credit entities that otherwise would struggle to access funds. When coupled with EPC, the ESCOs repay the loan through the achieved cost-savings, and due to the interest rates, the budget dedicated for the RLF will increase over time and can be used to fund further upgrades. It has been successfully used in more than 30 states in the USA. Through one of the meetings with the stakeholders, the research team found that in Australia, the New South Wales (NSW) Government Finance Facility uses RLF for financing government building energy and water efficiency projects. The fund has been in place since 1998 and currently, has a cap of AUD$95 million. However, RLF may work better with shorter payback periods of up to four years. For projects with longer payback periods, slow project returns to the RLF will limit the rollout of new projects.
- **Green Bonds**: similarly to Environmental Upgrade Finance, in many cases they can be repaid through council rates. They are low-risk and Government-backed, and their issuance numbers are exponentially increasing worldwide, including Australia (Climate Bonds Initiatives, 2016). Nevertheless, they would require clearer rules, in particular around the definition of "Green" to avoid that unrelated applications are submitted to take advantage of the financial benefits of such mechanism.
- **Green Depreciation**: it implies an accelerated depreciation of green buildings, allowing tax deferment and therefore lower financial pressure early when the owner is still affected by the retrofit costs, and higher financial pressure when benefitting of energy and water savings. However, it does not solve per se the high upfront cost or the split incentive issues, thus it must be combined with one of the above. In addition, similarly to Green Bonds, a clear legislation is required to better control who can access this financial support mechanism.

Other options (e.g. grants) were identified, but the ones above were considered more effective or less exclusive. What it was found, however, was that the best solution would consist of a number of integrated financing options (e.g. on-bill financing for small remote projects, EUF or RLF for large projects) in order to overcome the respective individual limitations.

3.2.1. Post-retrofit M&V

This component is also critical for a successful retrofit project since, as explained, there is a need to verify that the predicted savings match the measured ones, as this is often not the case (Zhou et al., 2016). It is important to implement M&V policies promoting cyclic feedback mechanisms. As an example, the 2007 US "Energy Independence and Security Act" introduced a 4-year cycle for project plan, implementation and verification (USDE, 2012a). Importantly, the post-retrofit M&V may as well represent the first step of a new upgrade process, as it can be used to identify new savings opportunities.

3.3. Scenario modelling

The results of the prediction modelling exercise confirmed how the application of a number of best international practices in the Australian context would lead to substantial environmental benefits but, importantly, to high returns of investments, thus crafting a strategy to not only help coping with increasing pressures for cleaner technologies, but to abate the costs for governments and councils.

In Fig. 4, the BN results are summarized. The spider chart shows the predicted magnitudes of increase in the number of retrofitting projects for Australian hospitals for different scenarios, compared to the current baseline situation (set as 1). The model focuses on hospitals only as in Australia they represent the public building category with the highest stock size and energy/water consumption. The scenarios mainly account for the introduction of financial and procurement mechanisms, and they focus on two specific retrofitting strategies: (1) "low-hanging fruits" such as combined LED efficient lights for energy and tap aerators for energy and water, and (2) a more complex retrofit such as solar PV panels. The BN clearly reflects the pros and cons of the financial mechanisms as discussed in the literature, thus revolving loan funds (RLF) and environmental upgrade agreements (EnvUpAgr) would proportionally lead to a higher increase in retrofitting projects compared to less effective green depreciation and on-bill financing (On bill) strategies. In addition, combining a revolving loan fund with a more effective, EPC-type procurement, would further increase such multipliers. When evaluating different retrofitting options, the benefits of creating dedicated financial facilitation pathways for deeper retrofits (i.e. solar PV) represent a much more needed aid given the high capital costs, compared to LED and taps aerators which would have lower installation costs and thus a less insurmountable financial barrier. This is reflected by the BN outputs: in the best-case scenario analysed, i.e. when a revolving loan fund and an EPC procurement type are instituted, the number of solar PV - retrofit projects would increase 11-fold compared to the current state; this would further increase to 12.8 times the current rate once a high implementation rate has been achieved (High impl), based on the innovation diffusion rate theory (Rogers, 2010). In comparison, such multipliers for the LED + aerators scenario are respectively 6.1 and 7.9.

In the second part of this modelling work, i.e. the SD model, the BN outputs (i.e. predicted retrofitting rate, best financial/

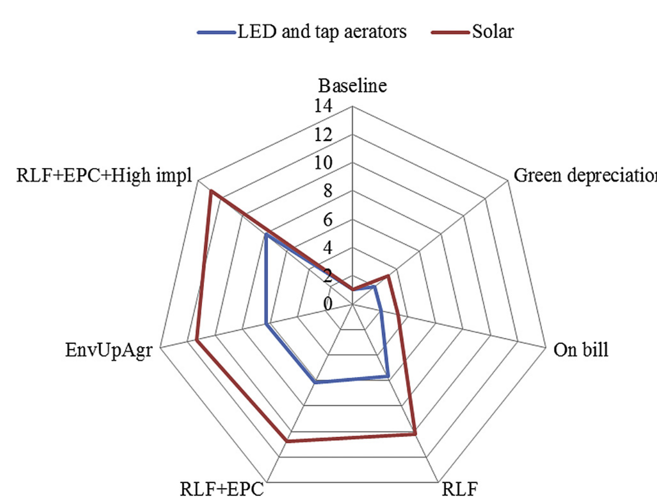

Fig. 4. Increase in completed retrofitting projects as per BN prediction for different scenarios.

procurement method) were used to predict potential benefits of setting up a revolving loan fund dedicated to eligible retrofitting projects. The projects considered were LED lights and tap aerators since, despite the predicted rate of increase in projects was lower than for the solar PV scenario in relative terms compared to current rates, the absolute predicted retrofitting rate was higher than for solar projects, given the current rate being already higher. In addition, simple energy efficiency solutions such as better lightning systems have been proposed for at least three decades (Rosenfeld and Hafemeister, 1988) and represent a perfect low-cost example of available savings for many Australian public buildings. The funding pool was optimised to increase the monetary benefits, and this was split differently based on hospital size (e.g. 5 million only dedicated to very small hospitals, 50 million for very large hospitals, etc.). The main conclusions were:

- An initial investment of AUD$80 million would be required to retrofit 29% of the hospitals in 5 years.
- The cost-savings for hospitals would be approximately AUD $380 in 10 years, i.e. almost 5 times the investment.
- Over 1700 GWh of energy would be saved in 10 years, as well as over 10,400 ML of water
- Over 21.5 million tonnes of CO_2-e would be avoided in a 10-year timeframe, helping the government achieve sustainability goals.

The models, especially the BN, rely on a number of assumptions, as it is logically supposed to be given the uncertainty around such modelled system and the missing data. Above all, the BN relies on a number of qualitative inputs provided by the stakeholders, who helped in quantifying links between variables (e.g. financial/procurement environment and retrofit attractiveness). However, the elicitation process has been performed in a rigorous and consistent manner to ensure the model is reliable and accurate. This was confirmed through the validation process as described in the Methods section. The models were applied to the specific context of Australian hospitals, as they are the category of public buildings responsible for the highest energy and water use; however, given their flexible structure and data entry process, they can be easily adapted for the other public building categories. Essentially, the implication of this model for the retrofitting industry is the quantification of the benefits (cost savings, carbon emission reductions) of introducing innovative financing and regulatory mechanisms dedicated to building water and energy efficiency projects in Australia; in turn such numerical evidence can be presented to key government decision-makers in order to push such changes forward.

3.4. Proposed retrofitting guidelines

EPC-based government building retrofitting guidelines from United States (Baechler and Webster, 2011), United Kingdom (DECC, 2015), Finland (Motiva Oy, 2009), Canada (Federal Building Initiative, 2013), Germany (Schmidt, 2010), IEA ECBCS Annex 46 (Shonder et al., 2010) were reviewed in terms of retrofit steps and relevant policies. In addition, retrofitting programs from five states in Australia were also analysed in terms of relevant policies and targets, implementation methods and current progress. The programs are:

1. Greener Government Building (GGB)– Victoria (Department of Treasury and Finance, 2016)
2. Government Resource Efficiency Policy (GREP) – New South Wales (NSW Office of Environment and Heritage, 2014)
3. Government Building Energy Strategy (GBE strategy) – South Australia (Government of South Australia, 2013)
4. Energy Smart Government (ESG) – Western Australia (Murphy, 2010)
5. Strategic Energy Efficiency Policy (SEEP) – Queensland (Queensland Department of Public Works, 2007)

The detailed review of the five Australian State Government's retrofitting programs was presented in (Zou et al., 2017). The review showed, in particular, that Victoria's EPC-based GGB program was successful in accelerating the retrofitting rate of their government building stock. The NSW's GREP program was also found to be making significant progress. These programs are successful largely because of having a mandate to achieve the target and using an EPC-based procurement method. The availability of a government fund in the form of a loan was also observed to be an important success factor. On the other hand, in Western Australia and Queensland, the lack of a stable and long-term building retrofitting program, of a financing mechanism and of accountability, were considered as the primary reasons for the failure of their respective programs. Based on the review, EPC-based public building retrofitting guidelines and an implementation strategy were developed. Fig. 5 shows the proposed public building retrofitting guidelines of this study. The figure also shows the required key pillars at each step of the proposed retrofitting guidelines. In the next sections, we provide more detail for each of the steps of the proposed guidelines.

3.4.1. Project planning

The project planning stage includes the formation of a project team, monitoring and exploring energy and water saving opportunities at the site, and checking the feasibility of an EPC project. Experience from Canada's Federal Building Initiative program demonstrated that a competent project team should include all key personnel responsible for the management and operation of the facility and representatives from the procurement, human resources, finance, engineering, and legal departments (Federal Building Initiative, 2013). A preliminary energy audit should be carried out for exploring energy savings opportunities and preparing proposals. In case of multi-building projects or for a bundle of similar government buildings, representative energy/water audits are recommended. To assess the feasibility of an EPC project, government-defined threshold values can be used. For example, in Germany, only sites with energy bills of 100,000 €/annum are viable for EPC. The Victoria's Greener Government Building retrofitting program in Australia recommends seeking an alternative

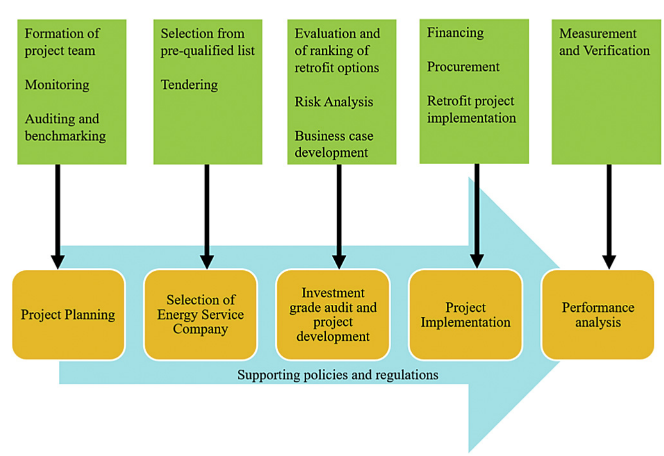

Fig. 5. Proposed guidelines for implementing EPC in a government building retrofitting project.

process to an EPC if the agency's total annual energy consumption is less than 1 GWh. During the project planning stage, the newly formed project team should also consider the risks associated with this retrofitting project and develop a management strategy to minimise those risks (Zou et al., 2016).

3.4.2. Selection of ESCO

Government building retrofitting programs that use an EPC should maintain a list of pre-qualified ESCOs that can provide required retrofitting services to the government. The pre-qualified ESCO list would help the government departments/agencies to select the most appropriate skilled professionals for each particular project. The ESCO selection criteria may include:

1. Capacity to comply with project requirements.
2. Demonstrated experience in the provision of energy/water efficiency retrofit services.
3. Organisation's methodology (auditing, selection and installation of retrofit measures and M&V) for undertaking an EPC project.
4. Organisation's risk management strategies.

If the potential for a project exists, a certain number of ESCOs can be invited to carry out a preliminary assessment including selection of potential energy/water conservation measures and estimates of energy/water and cost savings. Based on their submitted proposals, one ESCO could be selected to conduct the detail investment grade audit. In some countries (e.g. United States) one ESCO is selected directly from the pre-qualified ESCOs list based on certain criteria to conduct the investment grade audit.

3.4.3. Investment grade audit and project development

At this stage, the selected ESCO should perform a detailed audit, identify retrofitting options and submit a report that describes the basis for the project's contractually guaranteed savings. The investment-grade audit is equivalent to a Level 3 energy audit (for, specifically, energy retrofits). The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has developed three levels of auditing approach (Level 1, Level 2 and Level 3) that increase in detail and depth of analysis and cost (Cowan et al., 2004). Level 1 audit is not recommended for financial decision-making in capital intensive projects because of the inaccuracies associated with the energy savings estimation method. Level 2 audits are used as the basis for many decisions where the investment is modest, or large savings overshadow any uncertainty and risk. A Level 3 audit offers the most detailed engineering and financial analysis and is generally used for complex building retrofitting with significant capital investment (Cowan et al., 2004). Such Level 3 audit is costly, but significantly reduces the risks associated with costs and energy savings estimates, and therefore it is recommended for major retrofit projects.

To guarantee the minimum savings, the ESCO needs to assess the associated risks that can hinder their achievement. There are certain constraints that are unique to building retrofitting projects, such as financial and cost constraints, modelling constraints, technology and equipment constraints, policy and regulation constraints, work hour constraints, workspace constraints, material and equipment transportation constraints and surrounding environment constraints. These constraints place significant and unique risks to building retrofitting project design and management. Another important element of this stage is to develop a measurement and verification (M&V) plan for the project. It is essential to have a good M&V plan in an EPC based project because the repayment is done from the savings achieved as a result of retrofitting.

At the end of this stage, the ESCO should develop a business case proposal for the retrofit project and submit it to the project team. After reviewing the proposal, the project team decides on whether to.

(1) accept the report and implement the project,
(2) not to implement the project or
(3) request ESCO to amend the proposal to make it compliant with the requirement of the project team.

Once the report is accepted, the project team proceeds with organising the fund and developing an EPC.

3.4.4. Project implementation

The implementation stage starts with arranging the fund for retrofitting either from government or private sectors. Once the funding is approved, an EPC is signed between the department/agency and ESCO. The EPC contract includes the details of the agreed scope of works, maintenance schedules, project cost, guaranteed savings and M&V plan. Then the ESCO proceeds with installing the proposed retrofit measures. The installation of the proposed retrofit measures may either be carried out by the ESCO itself, or the ESCO can engage subcontractors to do the work. According to United States guidelines, the best practice during the implementation stage is to keep the ESCO and department/agency in contact to avoid delays, unintended outcomes, and backtracking.

3.4.5. Performance analysis

One of the most important keys to the success of an EPC is having a well-defined measurement and verification (M&V) plan to analyse the performance of a retrofitted building. Projects with a robust M&V plan result in a substantially higher (up to 20–30%) level of savings than projects that have little or no M&V. The M&V may include the requirement for certain energy and water efficiency installations to be measured and verified annually over the term of the EPC contract. It can be carried out by facilities departments of the retrofitted buildings. However, sometimes the government agencies lack the capacity to perform M&V themselves. In that case, the M&V can be carried out by the same company who worked during the exploration and selection of retrofit measures or by other external companies. The EPC contract should include the details about the responsibility of the ESCO and client in this performance analysis stage.

3.5. Implementation strategy

Following from the review of different government building retrofitting programs, lessons learnt from five Australian programs, and experts consultation, it has been realised that the effective implementation of any retrofitting guidelines and achievement of desired outcomes depends on the actions of four key stakeholders: (1) the government department in charge, (2) a facilitation team, (3) ESCO and (4) the government agency. Fig. 6 shows the key stakeholders and their interactions with each other at different stages of the proposed retrofitting guidelines.

The government department in charge has the responsibility of introducing the appropriate policies, regulations and mandates; establishing a reasonable target, providing funds to the eligible projects and monitoring the progress towards the preset targets. Government agencies in most cases may not have the expertise to engage and manage energy/water efficiency projects. The government department in charge is usually the one which holds and allocates the resources for retrofitting, e.g. the Department of Treasury and Finance in Australia.

Government personnel in most cases may not have the expertise to engage and manage water/energy retrofit projects. From the

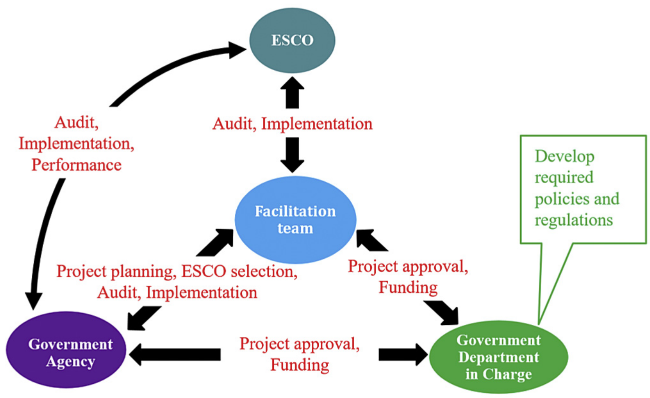

Fig. 6. Key stakeholders and their interactions for implementing the retrofitting guidelines.

best practice state level and international programs it was observed that the facilitation team can help the department/agency throughout the retrofitting process starting from project planning to implementation and completion. This team can help the government agency to assemble the right team and provide education and dedicated assistance while preparing a compliant report to make it eligible for funding from the government. In this way they can minimise the use of agency resources as well as the time required to implement the project. In Canada, such assistance is provided the by Federal Buildings Initiative (Shonder et al., 2010). Canada-Quebec and Germany have relied on assistance and guidance from non-governmental organisations (NGOs) and associations, as well as from contracting agents (Singh et al., 2010). Some of the same services are provided in Finland by Motiva, a state-owned company promoting energy efficiency and renewable energy sources. Motiva acts as a link between ESCOs and their potential clients by developing contracting models and tools, marketing the EPC concept (Motiva Oy, 2009). The role of the project facilitator in the U.S. Department of Energy's energy savings performance contract (ESPC) program – administered by Federal Energy Management Program (FEMP) – provides another model for delivering this assistance. FEMP project facilitators (PFs) are objective, expert consultants for technical, financial, and contractual issues who help optimize the financial value of ESPC projects. In Australia, the facilitation team in different state level programs (Department of Treasury and Finance, 2016; Government of South Australia, 2013; NSW Office of Environment and Heritage, 2014), also plays a significant role in implementing the energy efficiency projects in their respective states.

As mentioned in previous section, the role ESCO is very important to conduct audits, select energy and water retrofitting measures and develop a business case including estimates of installation costs, savings and payback periods. They are also responsible for the installation of retrofit measures and post-retrofit M&V to evaluate the performance of the retrofits. Finally, the government agency should have firm determination to retrofit buildings in their portfolio and take necessary steps by following the proposed retrofitting guidelines and seeking necessary assistance from the facilitation team and government department in charge.

3.6. Workshops outcomes and proposed strategies

Based on the feedback obtained from the stakeholders during the final workshops, the main issues/strategies discussed were grouped and analysed in the following sub-sections. Then, the identified barriers and opportunities, and proposed guidelines, were revised and refined in order to achieve a final set of recommendations, which could be (1) accepted by the stakeholders, (2) realistic for the Australian scenario, and (3) backed by data, modelling outputs, and the comprehensive literature review described previously.

3.6.1. Building efficiency assessment

Regarding the building efficiency assessment process, the two main areas identified as main barriers are related to (1) governance and (2) data. In terms of governance, both QLD and WA participants identified a lack of understanding of the importance of M&V within their government departments, especially at senior management levels; as a consequence, this implies a lack of mandates or funding allocated to M&V activities, and in turn not enough data collected for verification of potential (pre-retrofit) or achieved (post-retrofit) savings. The poor metering systems currently installed in a number of existing buildings are also making it difficult to access consumption data. In the scenario, instead, where monitoring data is available, the issue is typically the absence of qualified experts within their organisations able to interpret such data. There seemed to be a lack of operation and maintenance support in government agency buildings. Also, there are few appropriate key performance indicators (KPI) for a baseline assessment of a particular buildings' efficiency.

Some potential solutions were identified; the stakeholders largely agreed on the need for mandates and standards. If mandatory energy/water consumption reporting and targets were introduced, this would trigger an inevitable investment in M&V activities to ensure that estimated savings are verified or otherwise. However, it was also mentioned that appropriate budget should be allocated for the efficiency assessment task if a mandate is introduced. Another most frequently mentioned coping strategy was related to educating staff to raise awareness about the opportunities of energy and water retrofits. Mandatory short courses for staff were identified as a potential solution, as well as successful demonstration sites. In addition, introducing clear regulations and standards for the type of audit required based on the project/building categorisation, as well as the responsible persons to undertake it, was considered another crucial requirement for better quantifying retrofitting opportunities. To improve the quality of monitored data and get trusted information from auditing, it was suggested to use a blend of technology and engineering skills. A list of prequalified auditors would help the agency to select experienced professionals during the auditing stage. To determine the baseline, proper KPI should be established based on the characteristics of the agency buildings such as, the utility bills, size of property, number of people etc. Fig. 7 displays the current cycle impeding a wider M&V implementation (red boxes), and the proposed effective M&V action plan (green boxes) based on a number of identified opportunities.

3.6.2. Financing

Fig. 8 lists the main identified financing barriers and coping strategies for government building retrofitting projects. There is presently limited specialist knowledge and experience within government agency for developing robust retrofit project business cases; therefore only limited funding allocations are available for retrofit project opportunities within annual budgeting cycles. Also, there is a lack of dedicated long-term funding sources for retrofitting projects. Individual government departments have a constrained budget for each fiscal period, and as a result, a potential retrofit project has to compete against other priorities. In addition, the reduction in operational costs may not be adequately

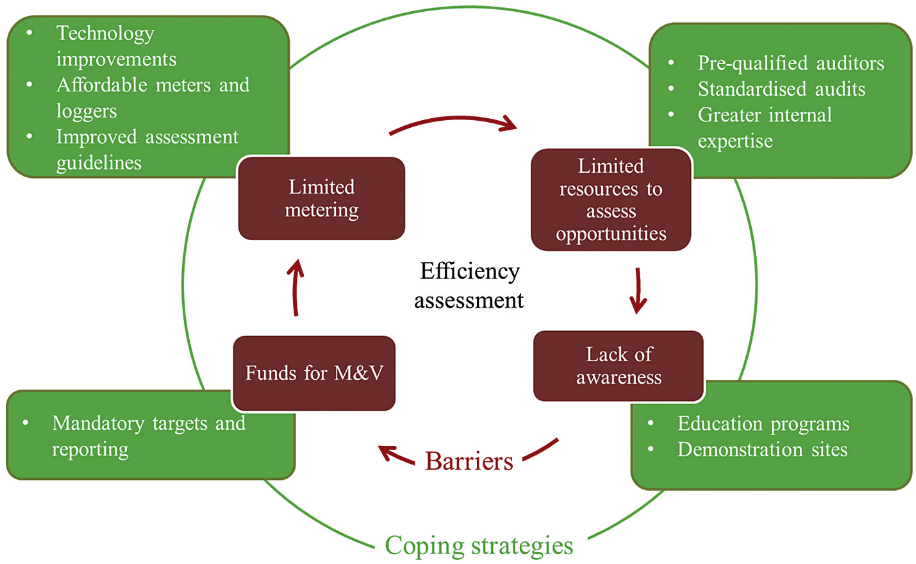

Fig. 7. Barriers and coping strategies for building efficiency assessment.

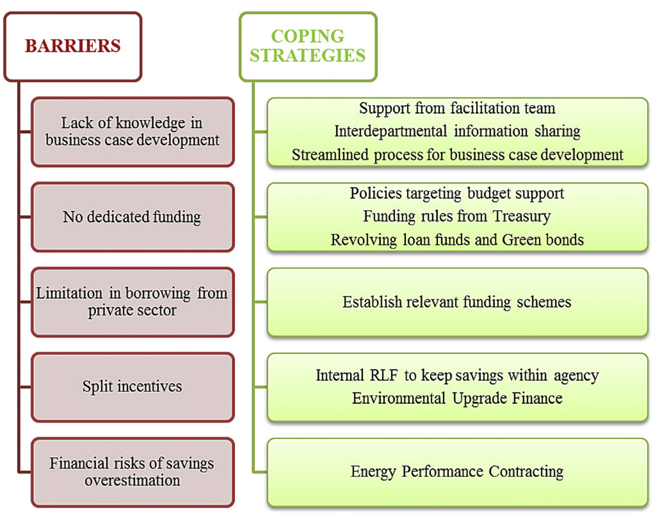

Fig. 8. Financial barriers and coping strategies.

considered in the project prioritisation process. Another issue is that governments have limited opportunities for borrowing from private sector lenders in order to fund public building retrofit projects and even if they can, often they are reluctant to borrow money or enter into a financial lease agreement for energy/water efficiency projects. Finally, in cases where public buildings are leased, there is little incentive for the government department tenant, as well for the owner, to retrofit (i.e. split incentive issue).

Even in cases where these initial barriers are overcome, and a particular government department successfully retrofits their buildings, then the ongoing operational savings from lower utility bills are usually not retained in that department, thus providing a disincentive to invest in projects that would in practice reduce their future budget allocations. In addition, with traditional procurement mechanisms, the financial risks of not achieving the desired savings target also act as a barrier to the financing of retrofitting projects.

In terms of coping strategies, it was agreed that governments could consider introducing targeted policies with allocated budget support for an ongoing retrofitting program, with the Department of Treasury establishing retrofitting project funding rules. A revolving loan fund was considered as a potentially effective financing option in the workshop, based on international/national evidence and modelling results; Green Bonds were also considered a valuable option alongside RLF, given the worldwide/national recent uptake of this funding mechanism (Climate Bonds Initiatives, 2016). A RLF could potentially provide a perpetual source of funding for viable retrofit projects, since annual retrofit operational savings and interest payments are returned to the capital pool. If an internal RLF, i.e. within a specific department, is arranged, this would provide an incentive for senior government executives to retrofit and accumulate the achieved savings over the following fiscal years. The modelling outputs of the research team back such preference. The government could also consider introducing policies, regulations and funding schemes that enable departments with viable retrofit projects to access private sector funding.

In case of leased public buildings, ad-hoc financing schemes (e.g. Environment Upgrade Finance) as discussed in previous sections could help resolve the split-incentives issue. A performance-based contracting method such as EPC procurement method would then minimise the financial risks associated with retrofitting projects. Finally, in order to help the agency in developing strong business cases for the retrofitting projects, the formation of an expert facilitation team as well as information sharing between departments would be critical. Establishing a streamlined process for business case development was also suggested.

3.6.3. Procurement

The availability of guidelines and appropriate procurement pathways for building retrofit projects was viewed as a barrier by the workshop participants. Another barrier identified was a lack of skilled contractors to suitably install building energy and water efficiency retrofits, and of a contractual means to ensure that contractors achieved estimated savings from those retrofits over the long term. Government officers at the workshops confirmed that, currently, building retrofit project procurement is challenging and time-consuming, and requires extensive project management to achieve successful outcomes. The final major barrier identified for procuring retrofit projects was related to the geographical and logistical challenges associated with the large states such as

Queensland and Western Australia. These state governments have thousands of owned and leased public buildings located within capital and regional cities as well as remote country towns. Planning for and procuring retrofit projects in regional and remote locations is particularly challenging. Bundling of retrofit projects across each state is possible but requires an expert procurement and facilitation team to be successful.

In terms of coping strategies, in addition to the already mentioned introduction of performance-based contracting mechanisms such as EPC, easy to follow procurement guidelines for various scales and categories of retrofit projects would help government officers championing building efficiency objectives. A list of pre-qualified contractors could help government departments and agencies to select the right contractor for particular retrofit project requirements. Government may also consider establishing a specialist building retrofit procurement office that can provide assistance to departments implementing smaller retrofit projects, and completely manage the entire process for geographically spread, large scale and bundled whole-of-government retrofit programs. Fig. 9 summarises the main identified procurement barriers and coping strategies for government building retrofitting projects.

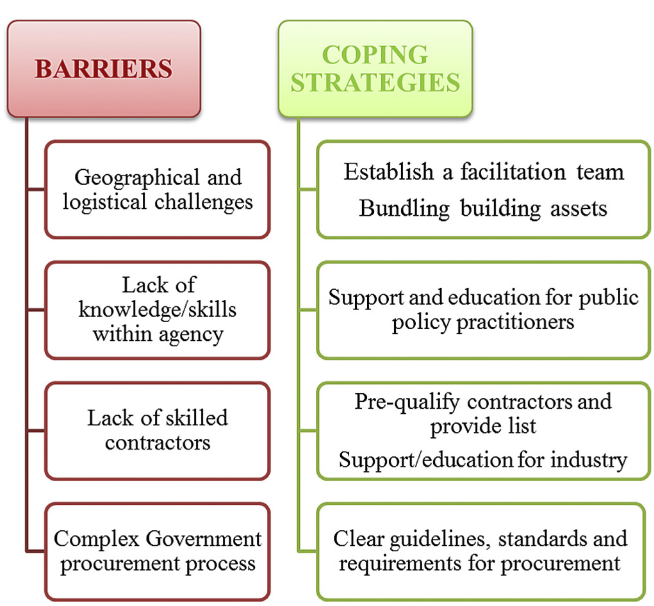

Fig. 9. Barriers and coping strategies during procurement.

3.6.4. Raising awareness through education

Education and raising awareness were previously identified as a critical link between the different retrofit activities, and one of the main drivers to improve the whole retrofit sector. However, this comes with a number of implementation issues, and potential solutions as illustrated in Fig. 10. Among the issues, the frequent changes in information dissemination and policy related to the energy/water efficiency priorities and targets of the government act as an impediment in this regard. Additionally, given that each government department or agency occupying a public building has a core business function, which is not building energy and water efficiency, the motivation to initiate and implement challenging retrofit projects will remain low in a policy context where such initiatives are voluntary and not mandatory.

To raise the level of awareness of water/energy retrofit opportunities and delivery methods, governments could consider the provision of training programs, dedicated information portals containing benchmarks, guidelines and case studies, as well as building assessment and procurement procedure manuals. Complementing awareness and training programs with executive leadership and well-defined and achievable mandates would ensure that viable retrofit projects are implemented. If compliance with building retrofit programs remains voluntary, the government could introduce performance rewards for those departments and agencies that have achieved savings targets. Mandatory government reporting of annual energy and water consumption for building stock with comparisons against best practice water and energy intensity KPIs may also promote a greater diffusion of these types of projects.

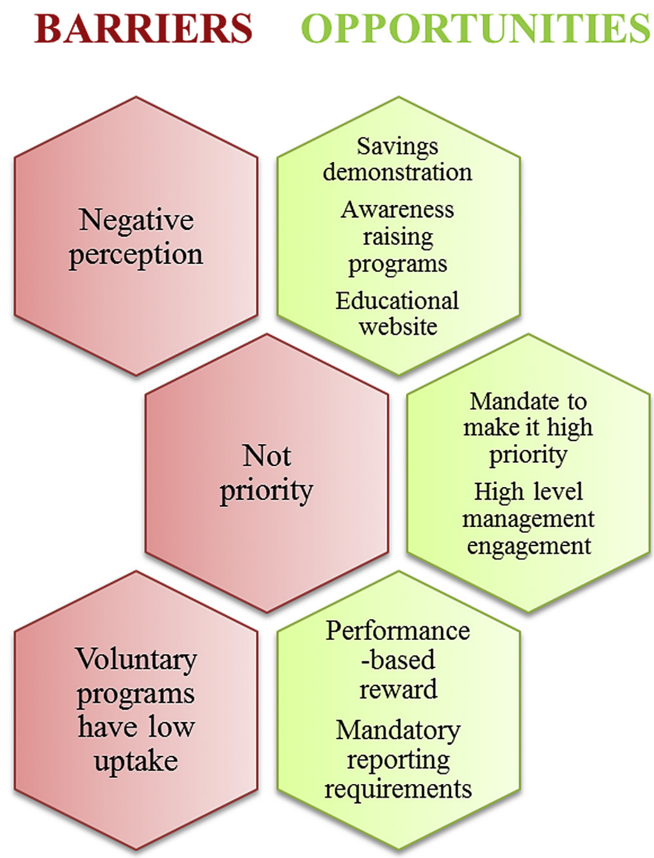

Fig. 10. Barriers and coping strategies for awareness raising.

3.6.5. Mandating efficiency targets

A further conclusion from previous activities of this research project was the importance of mandating efficiency-related targets. During the workshops, issues and coping actions were discussed in relation to this aspect.

As shown in Fig. 11, the three main barriers against mandating public building water/energy efficiency targets include: 1) partisan government policy; 2) issues with designing suitable targets; and 3) receiving acceptance by departments and agencies required to meet such targets. Firstly, whenever there is a change in government at the state or federal level, there are also significant shifts in sustainability-related policy, mandates and funding. Governments' willingness to take up energy and water efficiency projects is mostly influenced by 'net debt' over the forward estimate period (typically, this is four years in Australia). It is impossible to retrofit public buildings without increasing government net debt. The payback period of retrofitting projects is normally longer than four years and up to seven years, which means it will increase net debt

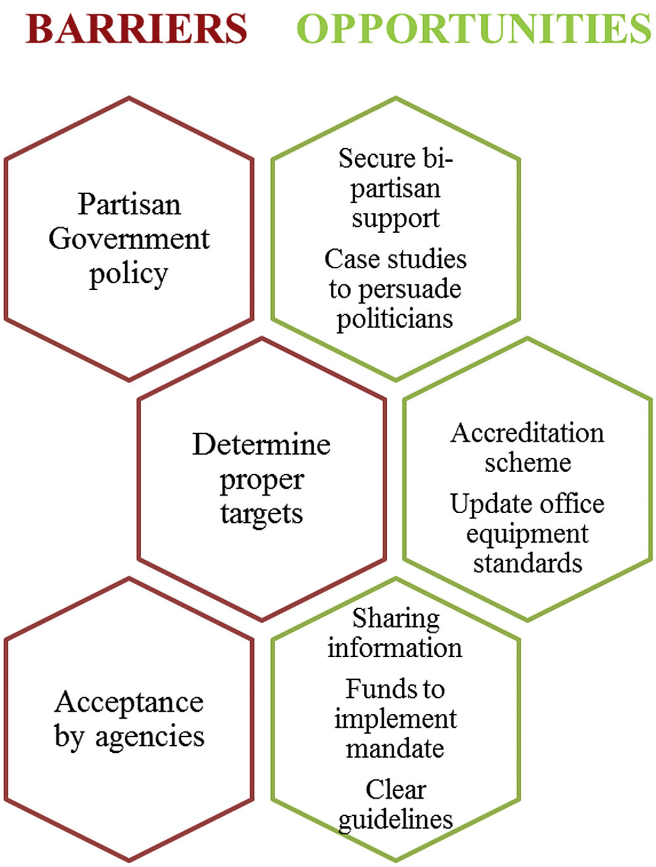

Fig. 11. Barriers against imposing a mandate and possible coping strategies.

over the forward estimates period. Although governments acknowledge the long-term benefits of building efficiency retrofitting, they give higher priority to reducing the amount of net debt over the forward estimate period. As a result, building retrofitting projects are seen as a cost rather than savings. One possible solution is to limit the project payback period to less than four years; but this will restrict the scale of investment. Alternatively, governments need to have firm determination and strong political will to impose appropriate policies and mandates to prioritise building efficiency upgrade projects. Successful case examples demonstrating savings and short payback periods can be used to persuade governments.

Designing a workable retrofitting mandate with savings targets that is sufficiently versatile to handle a wide range of building types and categories is undoubtedly challenging and requires careful consideration, planning and funding committed before it will be accepted and successfully implemented by government facilities managers. However, any mandate must have realistic targets and implementation timeframes. As a first step, certain relatively easy retrofits that yield a predictable rapid return of capital could be mandated (e.g. LED lights and taps aerators as shown in the prediction modelling results). The available accreditation schemes could be used as a standard while setting a target. An update of the office fit-out standard accommodating the energy and water efficiency features can also be a good way of achieving the retrofitting target in office buildings. It is important to note that any mandate set by government on its departments and agencies must be suitably resourced (i.e. funding, procurement support, guidelines, staffing, etc.) to ensure timely implementation.

3.6.6. Facilitation team

Outcomes of this project showed that the establishment of a facilitation team would greatly enhance the level of engagement of the interested parties and set up an easier and smoother retrofitting implementation process. During the workshops, barriers and coping strategies for the establishment of such facilitation team were discussed and illustrated in Fig. 12.

Considerable cost and effort is required to establish a skilled retrofit program facilitation team. A whole-of-government approach is required, where the central government creates the core team of project initiation and procurement experts along with a network of dispersed water/energy efficiency champions within various departments and agencies. The delivery of some significant retrofit projects by the facilitation team will serve to demonstrate the value of their service, which is currently understated.

There is a possibility of having certain conflicts of interest where a person has a role within the central facilitation team and also within a department or agency. However, this can be overcome through a transparent internal appointment process, and/or the use of specialist consultants for contracted periods (e.g. 3 years).

4. Conclusions

This paper describes the outcomes of a research project seeking to identify the main challenges and coping strategies for accelerating the retrofitting rate of public buildings in Australia. A hybrid mixed-method approach, combining data collection, interviews and scenario modelling was employed, where relevant stakeholders from government and the private sector were engaged throughout the project by providing input and feedback to the research team, and thus making the project outputs more credible and viable. The following are the key-findings of this research project:

1. Firstly, through the review process, a number of key steps for a successful retrofitting program were identified. These not only include suitable financing and procurement models (often identified as the only requirement), but also other overlooked components, such as education and usage metering. Experts helped validating and refining these results during a number of workshops.
2. Developed prediction models also showed potential for financing and procurement methods such as revolving loan funds coupled with performance-based contracting to create very high returns of investment and remarkable carbon

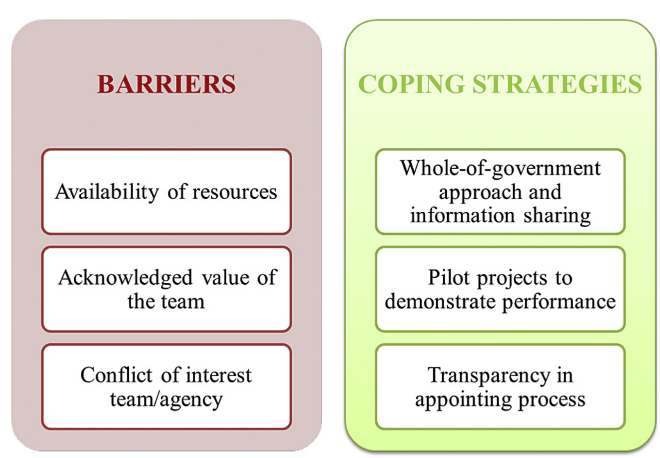

Fig. 12. Barriers to establishing a facilitation team and possible coping strategies.

emission reductions. Such results, backed by successful international examples, were presented to the stakeholders who show interest in revolving loan funds as they could provide a perpetual, internal source of funding for viable retrofit projects.

3. Based on the review of relevant guidelines used around the world, this research has developed new Public Building Retrofitting Guidelines. The review of these guidelines and stakeholders' consultation revealed that the effective implementation of such guidelines would depend on the collective actions of four key stakeholders:
   - The government department in charge;
   - The facilitation team;
   - The Energy Service Company (ESCO); and
   - The government agency.
4. Following two final workshops, a refined list of main challenges and coping strategies was prepared. Government's lack of willingness to introduce energy/water efficiency programs and appropriate mandates was identified as a major barrier to the public building retrofitting process.

It is anticipated that the outcomes of this project can be used by the stakeholders in order to implement the recommendations and facilitate the installation of retrofitting technologies in existing Australian public buildings. If this is achieved, water and energy consumptions would be drastically reduced (as well as costs for the governments); also, by reducing consumption and using cleaner energy sources (e.g. solar), GHG emissions would be drastically reduced, thus helping cities to partially contribute to mitigating climate change.

Acknowledgments

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