



REVIEW ON GREEN BUILDING RATING TOOLS WORLDWIDE: RECOMMENDATIONS FOR AUSTRALIA

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Abstract. Buildings could be led to adverse impacts on environment, such as generation of construction and demolition waste, and emission of greenhouse gases (GHG). Therefore, promotion on development of green buildings is in need. With the increasing awareness in sustainable development, various rating tools are promoted to evaluate the performance of green buildings. Nowadays, these tools function as a guideline for green building development. There are various green building rating tools developed worldwide, and various countries follow different rules, incentives and regulations. However, despite of promotion of green building rating tools, environmental issues from buildings are still significant in Australia. This research compared green building rating tools in Australia and other countries or regions around the world. This research found that rating tools in Australia lack of (1) mandatory criteria and (2) regulations and incentives. This paper recommended that governmental incentives should be promoted.

Keywords: green building, assessment tools, rating tools, Australia.

Introduction

Construction sector is regarded as one of the significant consumers of energy and generators of greenhouse gases in Australia and the worldwide (Reidy, Lederwasch, & Ison, 2011). United States Green Building Council Research Committee (2008) mentioned that buildings in USA were responsible for 38% CO₂ emissions, 71% electricity consumption, 39% energy use, 12% water consumption and 40% non-industrial waste. The construction sector consumed a large quantity of energy and emits 57% CO₂ in the United Kingdom (European Information Service Commission, 2012). In addition, depletion of natural resources might be caused by construction activities. For instance, about 40% of the raw stones, gravels and sands, 25% of virgin wood, and 16% of water used each year were used for construction globally each year (World Watch Institute, 2015). Therefore, environmental construction, operation and demolition of buildings should be promoted. The concept of green buildings was presented in the recent years.

United States Green Building Council (2007) identified green buildings as an efficient building operation in inte-

grated planning, site orientation, energy-saving technologies, on-site renewable energy-producing technologies, light-reflective materials, natural daylight and ventilation. According to Chan, Qian, and Lam (2009), green buildings could reduce negative impacts from buildings on energy consumption and environment. However, DuPlessis (2007) argued that it might be difficult for the construction industry to operate in this social ecological and responsible method, because there is a lack of standard to evaluate the performance of green buildings. Therefore, green building rating tools were developed (Hoffman & Henn, 2008) to assess performance of buildings and act as a solid yardstick in evaluation (Eichholtz, Kok, & Quigley, 2010).

The primary role of a green building rating tool is to provide a set of criteria for contractors and designers to achieve higher environmental performance (Cole & Larson, 1999). Nowadays, there are varied green building rating tools serving for different purposes.

Building Research Establishment Environmental Assessment Method (BREEAM) was launched as the first

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rating tool (Building Research Establishment Environment Assessment Method [BREEAM], 2015). Moreover, the most widely one at present was introduced by the United States Green Building Council (USGBC), named Leadership in Energy and Environmental Design (LEED) (United States Green Building Council, 2015b). LEED is accepted and used in various countries with 1.85 million square feet of construction space certifying every day (United States Green Building Council, 2015c). Green building rating tools such as Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, Green Mark in Singapore were discussed and evaluated widely (Crowley & Aho, 1999; Gowri, 2004; Haapio & Viitaniemi, 2008; Reed, Wilkinson, Bilos, & Schulte, 2011). In Australia, Green Star, Building sustainability index (BASIX) and nationwide house energy rating scheme (NatHERs) are supported and used by authority.

There are numerous researches focusing on the comparison of different rating tools. Mattoni et al. (2018) compared five green building rating tools, including CASBEE, Green Star, BREEAM, LEED and ITACA. Similarly, Doan et al. (2017) analyzed the differences and similarities among BREEAM, LEED, CASBEE and Green Star (New Zealand). Suzer (2015) compared LEED with BREEAM, SBTool, CASBEE, and Green Star. Asdrubali, Baldinelli, Bianchi, and Sambuco (2015) evaluated LEED and ITACA based two residential buildings.

Since various rating tools are introduced for green building development, a green building should be designed and constructed based on the selected green building rating tool. Furthermore, financial incentives are provided to trigger the tendency to green buildings in certain countries. However, certain countries perform well in green building development, while others are not. According to Organisation for Economic Co-operation and Development [OECD] (2015), Australia is one of the top ten greenhouse gas emitting countries. In order to alleviate this issue, Green Building Council of Australia [GBCA] (2015a) allocates 20% of weightage for greenhouse gas reduction in green buildings when evaluating green buildings, which represents that if individuals aim to obtain a Green Star certification, requirements on GHG reduction shall be fulfilled.

He, Kvan, Liu, and Li (2018) evaluated a green building with a green star certification in Australia by LEED and recommended further improvements to achieve higher scores in LEED, because there are more requirements in LEED compared to Green Star. Therefore, the same building is evaluated based on different rating tools, and different results might be derived. Therefore, reviewing various green building rating tools provides possibility to identify the varied requirements and thus enhance the performance of the green buildings.

GHG emissions from manufacturing and construction industry had increase up to 22% in 2015. Moreover, construction industry is the second largest contributor to Australia's economy, which accounts for approximately 8%

of GDP. Since 1990, there is a steady growth in the construction industry (Department of the Environment and Energy, Government of Australia, 2017c). However, increase in GHG emissions would be resulted by the steady growth of construction industry. Therefore, improvement in these green building rating tools and effective development of green buildings are in need. This paper aims to review the green building rating tools, and further provides recommendations for the green building development in Australia.

1. Classification of green building rating tools

There are various rating tools on green buildings, which are developed by different organizations and assess a building from environmental, social and economic perspectives. According to Baumann, Boons, and Bragd (2002), these tools could be categorised into six categories, including frameworks, analytical tools, checklists and guidelines, software and expert systems, and rating, ranking and organising tools. Figure 1 represents this classification.

From Figure 1, rating tools belong to the category of frameworks and checklists could provide basic knowledge of green buildings to their users. In addition, categories of analytical tools, software and expert systems, and rating and ranking tools are complex in nature. Moreover, Fenner and Ryce (2008) illustrated that environmental assessment tools can be classified into three types: 1) knowledge-based type which could serve as referential materials for designers; 2) performance-based type which use life-cycle impact assessment and simulation tools for calculations, such as energy consumption, lighting and indoor air quality; and 3) building rating type which is a credit rating calculator to assist designers in identifying design criteria and in documenting proposed design performance. Furthermore, categories of frameworks, checklists and guidelines on green buildings are included in environmental assessment tools of knowledge-based type. For instance, *ISO 15686-5:2017: Building and construction assets – service life planning – Part 5: Life cycle costing could be classified as a knowledge-based type for the life-cycle calculation* (International Standards Organisation [ISO], 2017). The performance-based type includes analytical and software and expert system rating tools. For example, software packages such as SimaPro and GaBi could be identified as a performance-based type. Finally, the category of rating, ranking and organising tools ranks the 'greenness' of buildings by stars or levels of certification. Green Star Design and As Built version 1.1 is an example as a rating tool. Furthermore, three steps are included in the rating process: 1) classification which refers to expectations of environmental changes and investigates inputs and outputs; 2) characterization which identifies the impacts from each input and output; and 3) valuation by weighting the impacts (Awadh, 2017; Fenner & Ryce, 2008). For example, nine key criteria are listed in Green Star Design and As Built version 1.1, which identify the

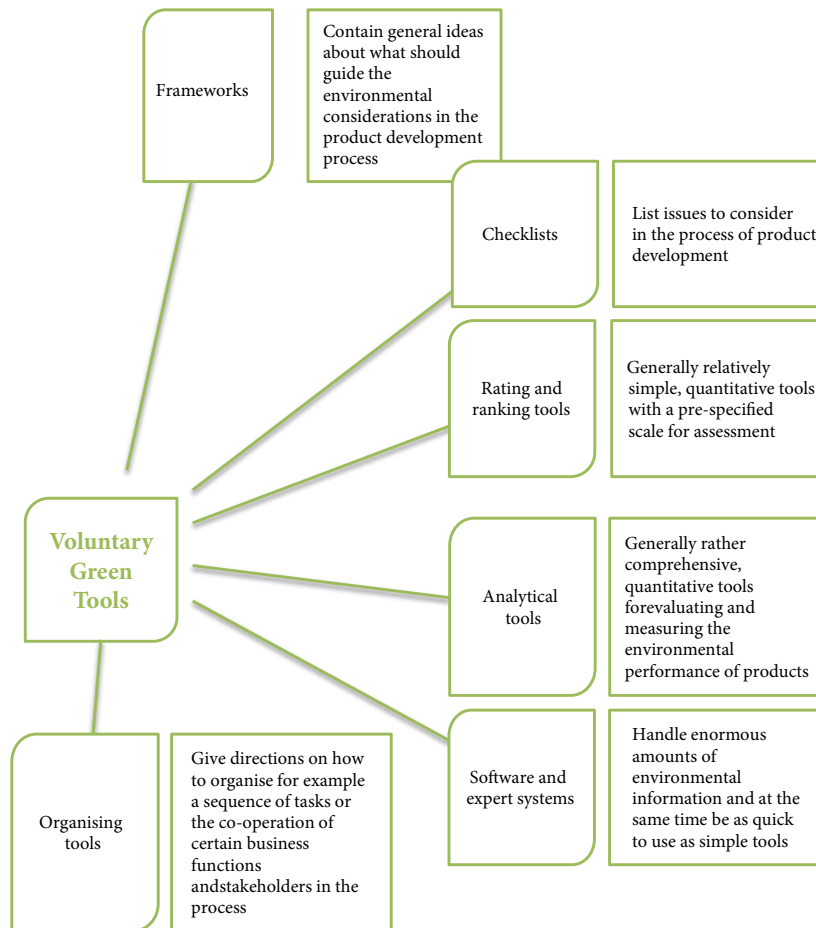


Figure 1. Classification of green building rating tools

impacts. According to Seo, Tucker, Ambrose, Mitchell, and Wang (2005), rating tools could provide indicators on quantitative performance to assist decision-making on designs. Additionally, performance levels of buildings are measured by stars in Australian context.

Categories of frameworks and checklists are usually used for rating and analysis. Furthermore, many researches had been carried out by using analytical tools, such as SimaPro (Geng et al., 2017; Ness, Urbel-Piirsalu, Anderberg, & Olsson, 2007; Pieragostini, Mussati, & Aguirre, 2012; Rebitzer et al., 2004; Saibuatrong, Cheroennet, & Suwanmanee, 2017). In Australia, assessment tools give a quantitative output to support decision making among alternatives. In addition, the rating type illustrates the performance based on agreed standards. This research considers the “rating tools” that measures the performance of the green buildings based on set criteria and standards.

There are varied green building rating tools developed by different countries, the aiming to reduce adverse impacts on environment during both construction and management phases (Asdrubali et al., 2015). Usually, the contents of those tools include considerations on environmental issues, and cover different phases in the life cycle of a building. Different tools are used to assess different buildings types (residential or office building), which

could be used globally. Therefore, selection of rating tools would be significantly important (Haapio & Viitaniemi, 2008). When developing a green building rating tool, environmental quality of buildings should be taken into considerations during design and construction phases (Kohler, 1999). The performance criteria on design must be verified during the construction and commissioning (Kohler, 1999). In order to reduce the adverse impact on the environment from buildings, environmental assessments should be carried out from the initial design stage of a project (Crookes & de Wit, 2002).

Related stakeholders might have different interests. For instance, a building owner might expect the increase of its price, whereas occupants might concern the indoor air quality, residential comfort, and safety issues (Ding, 2008). Therefore, using a single method to assess a building might not satisfy all the demands from its users. However, an ideal environmental green building rating tool would include all the requirements from related parties (Ding, 2008).

During the last decades, voluntary approaches and financial initiatives have been increasingly promoted in the construction sector to improve environmental performance (United Nations, 2004). Nowadays, there are many green building rating tools developed, launched and ac-

cepted by the public. They are widely used to assess the performance of green buildings worldwide (Asdrubali et al., 2015; Cole, 2005; Ding, 2008; Forsberg & Von Malmberg, 2004; Gowri, 2004; Haapio & Viitaniemi, 2008; Reed et al., 2011). Therefore, it is necessary to identify the green building rating tools around the world.

2. Research methodologies

World Green Building Council is one international organisation with a network of national green building councils in more than hundred countries, who influences the green building market significantly (World Green Building Council [WGBC], 2018). With one hundred thousand buildings and almost one billion square metres of green building space registered, the strong global network of world green building council is a significant force in social and environmental changes (WGBC, 2018).

There are three different kinds of membership in WGBC: established green building councils, emerging green building councils and prospective green building councils. According to WGBC (2018), an established green building council is stable and national positioning. An emerging green building council would develop its organisation where it is operational, providing with various programmes and financial initiatives. In addition, a prospective green building council would bring together a robust group of founding members, develop a strategic plan for further development and operation as a legal entity (WGBC, 2018).

Countries with established green building councils would establish a stable and integrated functional system to evaluate and develop green buildings. However, the development of green buildings in the countries with emerging and prospective green building councils is at the initial stages. The research and analysis on these countries might fail to provide a significant reference value to further study in green building development. Therefore, countries with established green building councils are selected in this study. Furthermore, the green building rating tools used by established green building councils are listed in Table 1.

Based on Table 1, there are five major geographical areas. Each of these areas uses different rating tools based on different conditions. Therefore, a thorough investigation on each region is carried out. There are certain green building rating tools which are not widely used and are not published by an established green building council in the region. For instance, GSAS (Global Sustainability Assessment System) is a green building rating tool which is developed in Qatar. According to the WGBC (2018), Qatar has an emerging green building council, and this tool is not widely used within the region. Similarly, there are many countries with emerging green building councils. Several green building rating tools are not commonly used. Therefore, those rating tools are not included in this study. However, there are certain countries with established green building councils, but tools such as LEED

are more commonly used compared with tools developed in the specific countries. For example, in UAE, 'Estidama' is used in many government projects. However, the most commonly used rating tool is LEED. Under such circumstances, the more widely used tools, such as LEED are taken into consideration in this research. Consequently, there are 27 countries with established green building councils (WGBC, 2018). These selections are discussed in detail in the following sections. After analysing the green building rating tools and relevant incentives schemes in selected countries, this study will investigate and compare the green building assessment tools and incentive schemes in Australia and other five regions.

2.1. American region

Based on Table 1, American region includes seven countries: Argentina, Canada, Brazil, Chile, Colombia, Peru and United States. LEED is used as a major green building rating tool in all these countries. Although that Alta Qualidade Ambiental (AQUA) process is used in Brazil, LEED is used by most users (Gomes, Silva, Lamberts, Takaoka, & Ilha, 2008). In July 2013, the number of projects registered amounted to 769 (over 33 million m² undergoing certification), with 109 certified in LEED (Ernst & Young Global Limited & Green Building Council Brazil, 2013). There are eight main criteria to evaluate green buildings in LEED, including location and transport, sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality (IEQ), regional priority and innovation. Additionally, in LEED, one credit point is allocated to the cost of green buildings, while the cost is not taken into consideration in many rating tools (Gan, Zuo, Ye, Skitmore, & Xiong, 2015).

According to Matisoff, Noonan, and Flowers (2016), green building policies in United States require LEED certification or equivalent design and performance in construction sector. In addition, these requirements often apply to government buildings. Despite of this, five states in United States offer limited grants to cover certification costs, while ten states offer tax deductions for certifying firms (Matisoff et al., 2016). Some local governments in the United States enact various innovative policies and incentives to promote green buildings, including property tax reassessment moratoriums, green funds, parking incentives, electric bill discounts and green roof mandates (Matisoff et al., 2016).

2.2. European region

European countries, such as Croatia, France, Germany, Netherlands, Poland, Spain, Sweden, Turkey and United Kingdom have established green building councils (Table 1). In Europe, there are five green building rating tools being widely used, including LEED, BREEAM, DGNB in Germany, VERDE in Spain and Haute Qualité Environnementale (HQE) in France. While DGNB, VERDE and HQE are established tools, they are illustrated in German,

Table 1. Green building rating tools in different countries

| Country | Region | Name of the green building council (GBC) | Green building rating tool |
|----------------|-------------------------------------|--|--|
| Argentina | America | Argentina GBC | LEED |
| Australia | Asia-Pacific | GBC Australia | Green Star |
| Brazil | America | GBC Brazil | LEED Alta Qualidade Ambiental (AQUA) |
| Canada | America | Canada GBC | LEED Canada Green Globes |
| Chile | America | Chile GBC | LEED |
| Chinese Taipei | Asia-Pacific | Taiwan GBC | EEWS (Ecology, Energy saving, Waste and Health) LEED |
| Columbia | America | Columbia GBC | Selo Ambiental Colombiano para las Edificaciones (SACE) [Colombian Environmental Seal for Sustainable Building] |
| Croatia | Europe | Croatia GBC | LEED BREEAM DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) |
| France | Europe | France GBC | HQE (Haute Qualité Environnementale) |
| Germany | Europe | German Sustainable Building Council | DGNB BREEAM Germany |
| Hong Kong | Asia-Pacific | Hong Kong GBC | BEAM Plus (Building Environmental Assessment Method) |
| India | Asia-Pacific | Indian GBC | IGBC (Indian Green Building Council) Rating LEED |
| Japan | Asia-Pacific | Japan Sustainable Building Consortium | CASBEE (Comprehensive Assessment System Built Environment Efficiency) |
| Jordan | MENA (Middle East and North Africa) | Jordan GBC | LEED |
| Malaysia | Asia-Pacific | Malaysia Green Building Confederation | Green Building Index |
| Netherlands | Europe | Dutch GBC | BREEAM |
| New Zealand | Asia-Pacific | New Zealand GBC | Green star adapted from Green Star Australia) |
| Peru | America | Peru GBC | LEED |
| Poland | Europe | Polish GBC | LEED BREEAM |
| Singapore | Asia-Pacific | Singapore GBC | Green Mark |
| South Africa | Africa | GBC South Africa | Green Star SA (adapted from Green Star Australia) |
| Spain | Europe | GBC Espana | VERDE (Green)(From SB Tool) BREEAM LEED |
| Sweden | Europe | Sweden GBC | BREEAM SE (Swedish version) LEED |
| Turkey | Europe | Turkish GBC | BREEAM LEED DGNB |
| UAE | MENA | Emirates GBC | LEED BREEAM ESTIDAMA (Sustainability) |
| UK | Europe | UK GBC | BREEAM |
| USA | America | US GBC | LEED Green Globes |

Spanish and French. BREEAM is widely used in Europe, which includes ten criteria: management, health and well-being, energy, transport, water, material, waste, land use and ecology, pollution and innovation.

Apart from the rating tools on green buildings, there is a wide variety of incentives introduced in Europe to

stimulate promotion of green buildings. These incentives could be categorised into three types: 1) financial and fiscal incentives; 2) economic incentives; and 3) promotion and awareness incentives. According to Brillhante and Skinner (2015), the key strategy in European Union (EU) is to regard energy efficiency as a compulsory aspect

which should be considered in all national building codes. Cansino, Pablo-Romero, Román, and Yñiguez (2010) illustrated that tax incentives together with promotions, such as quota obligations and price regulation are enacted in 27 members in European Union. Furthermore, an exemption on payments of electricity use when the electricity is generated from renewable energy sources is provided to few countries, such as Germany, Romania, Slovak Republic, Denmark, Sweden and Poland (Cansino et al., 2010). In addition, tax incentives in personal income are available in Belgium, France, Czech Republic and Luxembourg (Cansino et al., 2010).

According to International Labour Organisation, European Union, and International Institute of Labor Studies (2014), environmental taxes and charges are the most widely used instruments to promote green policies in the European Union. Subsidies and tax deductions have been granted for energy efficiency enhancement in various fields, including buildings.

2.3. Asia-Pacific region

There are numerous green building rating tools launched by respective green building councils in the Asia-Pacific region (Table 1). Australia, Taiwan, Hong Kong, India, Japan, Malaysia, New Zealand and Singapore represent Asia-Pacific region. Green Building Council in New Zealand adapted Green Star from Australia, and started to use the tool since 2007 (New Zealand Green Building Council, 2015). LEED is used as one vital rating tool in India and Taiwan. In addition, India and Taiwan are also included in the top ten countries or regions who use LEED with largest certified areas, with 13.24 million gross square metres (GSM) and 3.84 million GSM respectively (United States Green Building Council, 2015a). However, commencing from 1 July 2014, projects in India aspiring for LEED certification are required to register with IGBC. Moreover, "LEED India" projects which are already registered with IGBC before July 2014, could only continue using IGBC certification till June 2018 (Indian Green Building Council, 2014).

Energy efficiency, water efficiency, environmental performances, IEQ and other green features are considered in Green Mark rating tool. Moreover, Green Building Index also takes energy efficiency, indoor environment quality, sustainable site planning and management, material and resources, water efficiency and innovation into account. 6 criteria are listed in BEAM Plus from Hong Kong, including site aspects, material aspects, energy use, water use, indoor environment quality and innovation and additions. Sustainable architecture and design, site selection and planning, water conservation, building material and resources, indoor environment quality and innovation are considered in IGBC. CASBEE from Japan is different from other rating tools used in the Asia-Pacific region (Gan et al., 2015). Two types are included in this rating tool, such as Built Environmental Quality (Q) and Built Environmental Load (L). Targets of energy efficiency, resource

efficiency, local environment and indoor environment are re-categorised under the Q and L types (Comprehensive Assessment System for Built Environment Efficiency [CASBEE], 2015).

According to Ernest & Young (2017), Malaysian government introduced tax incentives for green technologies to develop and strengthen green technologies. Moreover, there are four types of tax incentives: 1) tax incentives for the use of energy from renewable resources; 2) tax incentives for energy conservation; 3) income tax stamp-duty incentives for GBI certified building; and 4) Feed-in Tariff system (Hashim, Zakaria, Ahzahar, Yasin, & Aziz, 2016).

In order to maintain Singapore's image as a "city in a garden", Singapore government introduced 35 funding and incentive schemes related to energy efficiency and clean energy, green buildings and construction, water and environmental technologies, green transport and shipping, waste minimisation, environmental initiatives, and capability development (Tray, 2017).

2.4. Middle Eastern and North African region

Middle Eastern and North African region, Jordan and United Arab Emirates (UAE) are using LEED as their major green building rating tool, while Estidama is also used as the most significant green building rating tool in UAE. According to United States Green Building Council (2015a), UAE has 3.13 million GSM of certified space, and is one of top ten countries with LEED certificated areas. Separate green building regulations are applied to government buildings in Dubai and UAE, which would enforce industry wide (Salama & Al-Saber, 2013).

2.5. South African region

In South Africa, Green Star from Australia is used as the major green building rating tool (Green Building Council of South Africa, n.d.; New Zealand Green Building Council, 2015). South Africa Bureau of Standards (SABS) developed a set of standards to provide a framework for energy-efficiency, and minimum requirements for best practice of green buildings (Gunnel, 2009). Sustainable building assessment tool (SBAT) is another green building rating tool used in South Africa (Gibberd, 2008). Although Green Star is designed to recognise leadership at the upper end of the green scale rather than functioning as a regulation, governments encourage the use of this tool (Gunnel, 2009). Green Building Council in South Africa supports not only the use of Green Star and also other four tools (Green Building Council of South Africa, 2018), including: 1) "EDGE" which focuses on carbon emission and reduction, water savings, and a lower cost of living in residential buildings; 2) "Energy Water Performance v1" which provides benchmarks for the energy and water consumption in existing buildings; and 3) "Net Zero" which investigates carbon, water, waste and ecology. However, all the four rating tools only focus on one or two aspects of green buildings.

3. Green building rating tools used in Australia

There are tools used in the whole Australia and some tools are in certain regions. BASIX is compulsory to be used in New South Wales (NSW) for residential buildings, and NatHERS is used to evaluate thermal efficiency. Furthermore, use of NABERS and BASIX could help to obtain credit points in Green Star. These tools investigate the performance of buildings from various perspectives. For example, BASIX only focuses on residential buildings. Table 2 provides descriptions and Table 3 lists the different criteria addressed by different tools, and further introduces the uses, applications and phases of life cycle for each tool.

According to Table 3, most of these tools focus on material use, water and energy consumptions, and indoor environment quality. The assessment tools are mostly focusing on only one criterion, and rating tools usually focus on

more than one criterion. However, tools such as NABERS concentrate on the performance of buildings. Tools such as Green Star investigate buildings from design perspective. There are few assessment tools observe the cost of these buildings (Table 3). All the rating tools except Green Star could be applied to separate ratings. Green Star considers all the criteria instead of focusing on sole perspective. Noise in the indoor environment quality is failed to be considered by the majority of rating tools. In addition, none of the rating tools take cost into consideration (refer Table 3).

According to GBCA (2015b), there are 663 green star certified projects in New South Wales, 13 in northern Territory, 514 in Victoria, 205 in Western Australia, 127 in South Australia, 27 in Tasmania and 367 in Queensland during October 2018. From 2004 to 2008, there were 124 projects certified in Green Star and there were 333 certified projects during last 12 months (GBCA, 2015b).

Table 2. Green building rating tools used in Australia

| Tool | Description | Reference |
|---------------------------------------|---|--|
| AccuRate | <ul style="list-style-type: none"> – Provides the benchmark for accrediting other software for use with the Building Codes of Australia requirements. – Allows for the physiological cooling effect of air movement, and the latest developments in international simulation techniques. | Shiel, Aynsley, Moghtaderi, and Page (2017) Berry and Marker (2015) Seo et al. (2005) |
| BASIX (Building sustainability index) | <ul style="list-style-type: none"> – BASIX was introduced 1st July, 2004 by the New South Wales (NSW) Government as a sustainable planning measure to be undertaken in Australia. – Implemented under environmental planning and assessment regulations 2000 and environmental planning policy 2004 and applies to all residential dwelling types. – The BASIX is a web-based assessment tool analyzing data relating to the design of the proposed dwelling and determines how this scores against water and energy targets. | NSW Department of Planning and Environment (2013, 2017) Eroksoz and Rahman (2010) Van der Sterren, Rahman, Shrestha, Barker, and Ryan (2009) Anderson (2006) Vijayan and Kumar (2005) |
| BERS (Building Energy Rating Scheme) | <ul style="list-style-type: none"> – Is a computer program and a powerful tool that is initially used to simulate and analyze the thermal performance of Australian houses in climates ranging from Alpine to tropical. – Was accredited for use for energy ratings for NatHERS from 1st May 2016. | Nationwide House Energy Rating Scheme (NatHERS) (2017) Energy Inspection (2017) Seo et al. (2005) |
| Ecospecifier | <ul style="list-style-type: none"> – Is an online database on environmentally preferable materials from glues to carpets to workstation fabrics which was launched in October 2003. – Ecospecifier aims to provide guidance and hard data in a form that's easy to use by designers and architects. – The service is also designed to allow close integration with designers and architects using the new Green Star rating system. | EcoSpecifier Global (2017) Verghese and Hes (2007) Lewis and Ryan (2006) |
| FirstRate | <ul style="list-style-type: none"> – FirstRate interactive is a tool with graphic user interface that enables designers and thermal performance assessors to generate energy ratings for a home by tracing over floor plans. – The software integrates the AccuRate calculation engine to estimate the annual heating and cooling energy and can be used to rate an existing design or as an interactive tool to optimise the design beyond compliance. – It is used by the majority of industry to rate the energy efficiency compliance of residential dwellings to the 6-star standard under the National Construction Code of Australia (NCC). – Tool generates ratings based on the NatHERS 0–10 star scale for homes. | Whaley, O'Leary, and Al-Saedi (2017) Victoria State Government (2017a, 2017b) Crawford, Bartak, Stephan, and Jensen (2015, 2016) Aldawi and Alam (2016) Alam and Ham (2014) Mansoury and Tabatabaiefar (2014) |
| Green Star | <ul style="list-style-type: none"> – Green Building Council of Australia (GBCA) was launched in 2002 as a national not-for-profit organisation focusing on the development sustainable property industry in Australia. In 2003, GBCA launched its green building rating system as "Green Star". – It includes four green building rating tools for Design and As Built, Interiors, Communities and Performances and also it assesses the sustainability of projects at all stages of life cycle. | GBCA (2015a, 2015b) Illankoon, Tam, and Le (2016a) Illankoon, Tam, Le, and Shen (2016b) Seo (2002) |

End of Table 2

| Tool | Description | Reference |
|--|---|--|
| NABERS (National Australian Built Environment Rating System) | <ul style="list-style-type: none"> – NABERS is a collection of separate tools, each of which calculates and rates the performance of an existing building (or part of one) on a particular environmental indicator at a certain point in time. – Can be undertaken individually (for example, a company may decide to rate its building only in energy and water), and they are not combined into an overall rating. – NABERS incorporates the tool formerly known as the Australian Building Greenhouse Rating tool (ABGR), now known as NABERS Energy, for offices, developed in 1999 by the NSW Sustainable Energy Development Authority. ABGR became part of the NABERS suite of tools in 2008 and has since been expanded to include water, waste, and indoor environment ratings and to cover a range of building types. | Office of Environment and Heritage, Government of Australia (2016) Mitchell (2010) Hertzsch, Heywood, Piechowski, and Rowe (2011) Baird (2009) Bannister (2005) Watson, Mitchell, and Jones (2004) |
| NatHERS (Nationwide House Energy Rating Scheme) | <ul style="list-style-type: none"> – NatHERS provides Australian homes with a star rating out of ten based on an estimate of a home's potential (heating and cooling) energy use. – Provides a “measuring tape” for energy efficiency. – Administered by the Department of the Environment and Energy on behalf of the states and territories of Australia. – NatHERS accredits BERS and FirstRate software for the assessment of energy loads and when rating houses. | Department of the Environment and Energy, Government of Australia (2017b) Shiel et al. (2017) Whaley et al. (2017) O'Leary, Belusko, Whaley, and Bruno (2016) Berry and Marker (2015) Graham (2003) |

Table 3. Detailed evaluation of green building assessment and rating tools used in Australia

| Tool | End Use | Applications | Phase* | Criteria | | | | | | | | | |
|--|----------|------------------------------------|----------|----------|------|-------|----------|-----------------------|-----------|---------------|--------------|-------------|------|
| | | | | Energy | Land | Water | Material | Environmental loading | IEQ – Air | IEQ – Thermal | IEQ – Visual | IEQ – Noise | Cost |
| AccuRate | Building | Residential building | D, O & M | ✓ | – | – | – | – | – | ✓ | – | – | – |
| BASIX | Building | Residential building | P and D | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – | – |
| BERS (Building Energy Rating Scheme) | Building | Residential building | D, O & M | ✓ | – | – | – | – | – | ✓ | – | – | – |
| Ecospecifier | Material | Building material | D, O & M | ✓ | ✓ | ✓ | ✓ | ✓ | – | ✓ | – | – | – |
| FirstRate | Building | Residential building | D, O & M | ✓ | – | – | – | – | – | ✓ | – | – | – |
| Green Star | Building | Buildings | D, O & M | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – |
| NABERS (National Australian Built Environment Rating System) | Building | Commercial & residential buildings | O & M | ✓ | – | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – |
| NatHERS (Nationwide House Energy Rating Scheme) | Building | Residential building | D, O & M | ✓ | – | – | – | – | – | ✓ | – | – | – |

Note: *P – Planning; D – Design; O & M – Operation and Maintenance; EoL – End-of-life.

This fact illustrates significant uptake of Green Star during the last few years and its diffusion across different states. According to GBCA (2015b), 58% of certified buildings are office building, 22% are office interiors. Educational buildings constitute up to 11%. Therefore, there might be increasing demands for the office buildings to be certified in Australia.

Tax breaks for green building programme were expected to be introduced to promote green building development across Australia. However, this program was scrapped, because of limited federal budget during 2012–2013 (GBCA, 2012). In Australia, tariff schemes, such as gross-feed-in-tariff scheme, a net-feed-in-tariff scheme and a buy-back scheme were enacted to encourage use of

renewable energies (Tam, Le, Zeng, Wang, & Illankoon, 2017). In addition, a solar credit scheme was initiated by the authority to support household owners with additional financial benefits for installing renewable energy systems (Tam et al., 2017). Moreover, governmental fundings amounting to \$2.1 million (GST exclusive) were provided for programme from 2014 to 2016 to encourage installation of renewable energy systems (solar photovoltaic panels or a solar hot water system only) in existing buildings (Department of the Environment and Energy, Government of Australia, 2017a).

4. Findings and discussion

This study identified various green building rating tools and incentives in five regions. In addition, green building rating tools in Australia are discussed in this study. Table 4 represents criteria of each rating tools discussed in this study.

Based on Table 4, certain aspects are considered by most of the rating tools. The key criteria such as energy and water consumption, sustainable sites, material, waste and pollution, management, and IEQ are mentioned by all the listed rating tools. However, there are differences in different rating tools. For example, the criterion on “environmental performance” covers up a wide range of aspects in Green Mark. Basically, it includes several sub-categories, covering sustainable construction, sustainable products, refrigerant management and greenery provision. All the sub-categories are related to environmentally friendly materials, resources and sustainable usage of sites. Energy efficiency is significantly considered in Green Mark. Illankoon, Tam, Le, and Shen (2017) mentioned that 49.73% of credit points on energy related criteria are allowed in Green Mark. According to Kamaruzzaman, Lou, Zainon, Mohamed Zaid, and Wong (2016), the main reason to the focus on energy is the expected energy hike in the future. Therefore, the reason to the concentration on “Energy” credits by most of the green rating tools is that these credits are promoted by international organizations, representing global concerns (Doan et al., 2017).

LEED also focuses on energy criteria (refer Table 4). Based on a comparison among BREEAM, BEAM Plus and CASBEE, LEED was found to be the most stringent and relatively less flexible in its assessment criteria in terms of energy use (Lee, 2012). Mattoni et al. (2018) reported that green building rating procedures aimed at reduction of energy consumption in the recent years. Despite of the stringent criteria, actual consumption of LEED certified buildings are comparable to BREEAM and BEAM Plus (Lee, 2012). In Australia, energy use is also the focus of Green Star. Green Star allocates 24 credits out of 100 on energy. In addition, no minimum requirements are developed as conditional requirements on energy (GBCA, 2015b). However, there are conditional requirements on energy in LEED and BREEAM, but developers are required to satisfy these requirements to obtain a certification. This

aspect is not in the Green Star. Therefore, in Australia, a green certification could be obtained without meeting all the basic criteria. Based on previous literatures, construction industry in Australia has contributed a large amount of GHG (Department of the Environment and Energy, Government of Australia, 2017c). One of the reasons could be a lack of minimum criteria in Green Star rating tool. Although Green Star Design and As Built rating tool allocate 20% of their credits on GHG emissions, reduction of GHG emission is not mandatory. Furthermore, a green building could still be certified without achievement of requirements on GHG reduction. Therefore, it is possible to obtain a green certification by achieving only two or three criteria out of eight. However, it is not the case in LEED and BREEAM, because they are mandatory. Therefore, there is a need to consider all the criteria holistically in Green Star when certifying Buildings. Development of a green rating tool which covers all the criteria is urgent.

There is a concern in sick building syndrome in Japan (Nakayama & Morimoto, 2009). Therefore, CASBEE focuses more on IEQ criteria. 17% of the credits are allocated to IEQ in Green Star (GBCA, 2015b). According to the survey conducted in Standing Committee on Public Works [NSW] (2001), 48% respondents experienced eight symptoms of sick building syndrome with moderate frequently. Therefore, Australia should focus on tools such as CASBEE for further improvements.

Some criteria, such as regional priority in LEED, life-cycle approach service and life-planning in BREEAM are not adopted in Green Star. According to Illankoon, Tam, and Le (2018), it is necessary to investigate life-cycle cost and regard it as a solution to first cost premium of green buildings in Australia. Therefore, life-cycle cost approach can be included in green building assessment if this aspect is included in Australian green building rating tools such as Green Star. Costs in evaluating buildings are considered in none of the rating tools in Australia (Table 3). Based on previous literature, initial cost is one of the main concerns in green building development (Davis Langdon, 2007; Hwang & Tan, 2012; Illankoon et al., 2016b; J.-L. Kim, Greene, & S. Kim, 2014; Zhang, Platten, & Shen, 2011). Therefore, ignorant of cost considerations in the green building rating tools would hinder the development of green buildings. If costs could be given attentions in the initial stages, development in green buildings might be enabled and the industry could find approaches to achieve a lower cost. Consequently, the first cost premium for green buildings would decrease as well. Software, such as GaBi, enables the life-cycle cost calculations for green buildings. These tools should be promoted. Additionally, criteria on cost should be introduced to green certification tools. Therefore, developers could consider cost as a part of green buildings evaluation, which would provide fruitful solutions to initial cost premium issues. It will be beneficial to develop a system to reward the developers who certify green buildings with a lower initial cost.

Table 4. Assessment criteria of various green building rating tools

| Green Star | LEED | BREEAM | Green Mark | Green Building Index | BEAM Plus | IGBC Rating |
|--|---|---|---|--|--|---|
| Ecological Value Sustainable Sites Heat Island Effect Light Pollution | Sensitive land protection High priority sites Surrounding density and diverse use Site assessment Protect or restore habitat Open space Heat island reduction | Proximity to amenities Site selection Ecological value of site and protection Enhancing site ecology Long term impact on bio diversity Building footprint | Greenery provision | Site selection Brownfield redevelopment Development density Environment Management Earthworks Greenery & roof | Contaminated land Neighbourhood amenities Ecological impact Cultural heritage Landscaping and planters Microclimate around the building | Site Preservation Basic amenities Proximity to building transport Natural topography and vegetation Preservation or transplantation of trees Heat island reduction, Non-roof Heat island effect |
| Greenhouse Gas Emissions Peak Electricity Demand Reduction Refrigerant Impacts Metering and Monitoring | Enhanced commissioning Green power and carbon offsets Enhanced refrigerant management Renewable energy Demand response metering Optimized energy performance | Energy efficiency Energy monitoring External lighting Low and zero carbon technologies Energy efficient cold storage Energy efficient transport Energy efficient equipment Impact of refrigerants | Building envelope Efficient ventilation Lifts and escalators Energy efficient practices Renewable energy Refrigerants | Minimum energy efficiency (EE) Performance Lighting zoning Electrical sub-metering Renewable Energy Advanced EE performance Enhanced commissioning Post occupancy commissioning EE Verification Sustainable maintenance (Energy related systems) Refrigerants and clean agents | Reduction of CO ₂ emissions/ alternative passive design Peak electricity demand reduction Embodied energy in building structural elements Ventilation system in carparks (EE) Lighting system in carparks (EE) Renewable energy system Air conditioning units Testing and commissioning Energy efficient appliances Operation and maintenance Metering and monitoring Energy efficient layout | Eco-friendly refrigerants Enhanced energy efficiency On-site renewable energy Off-site Renewable energy Commissioning Post-installation of equipment & systems Energy Metering and Management |
| Potable Water Stormwater | Rainwater management Outdoor water use reduction Indoor water use reduction Cooling tower water use Water metering | Water quality Water consumption Water monitoring Water leak detection and prevention Water efficient equipment Surface water runoff | Water efficient fittings Water usage and leakage detection Irrigation system and landscaping Water consumption of cooling towers Stormwater | Rain water harvesting Water recycling Water efficient irrigation Water efficient fittings metering and leak detection system Stormwater design | Annual water use Monitoring and control Water efficient irrigation Water recycling Water efficient appliances Effluent discharge to foul sewers | Landscape design Management of irrigation system Rainwater harvesting roof Water efficient plumbing fixtures Wastewater treatment reuse Water Metering Waste water during construction |

Continue of Table 4

| Green Star | LEED | BREEM | Green Mark | Green Building Index | BEAM Plus | IGBC Rating |
|--|---|---|---|---|--|--|
| Indoor Air Quality Acoustic Comfort Lighting Comfort Visual Comfort Indoor Pollutants Thermal Comfort | Enhanced indoor air quality strategies Low emitting material Construction IAQ Management plan Indoor air quality assessment Thermal comfort Interior lighting Daylight Quality views Acoustic performance | Visual comfort Indoor air quality Thermal comfort Acoustic performance Noise attenuation | Daylighting Artificial lighting Ventilation in carparks Ventilation in common areas Thermal comfort Noise level Indoor air pollutants IAQ Management High frequency ballast | Minimum IAQ performance Environmental Tobacco Smoke Control Carbon dioxide monitoring and control Indoor Air pollutants Mould prevention Thermal comfort Air change effectiveness Daylighting Daylight glare control Electric lighting levels High frequency ballast External views Internal noise levels IAQ before and during occupancy Post occupancy comfort survey | Security Plumbing and drainage Biological contamination Construction IAQ Management Outdoor sources of air pollution Indoor sources of air pollution IAQ in carparks increased ventilation Background ventilation Localised ventilation Ventilation in common areas Thermal comfort in AC premises Thermal comfort in naturally ventilated spaces Natural lighting Interior lighting in areas normally occupied Interior lighting in areas not normally occupied Room acoustics Noise isolation Background noise Indoor vibration Access for persons with disability | CO ₂ Monitoring Daylighting Minimum indoor and outdoor pollutants Outdoor views Low emitting material IAQ testing Occupant wellbeing facilities IAQ Management during construction |
| <i>Materials</i> | | | | | | |
| Life Cycle Impacts Responsible Building Materials Sustainable Products Construction and Demolition Waste | Building life cycle impact reduction Environmental product declaration Sourcing of raw material Material ingredients | Life Cycle Impacts Insulation Responsible sourcing of material Designing for robustness Recycled aggregates Speculative floor and ceiling finishes | Sustainable products Sustainable construction | Material reuse and selection Recycled content material Regional material Sustainable timber | Building re-use Modular and standardised Design Prefabrication Adaptability and deconstruction Rapidly renewable material Sustainable forest product Recycled material Ozone depleting substances Regionally manufactured material | Sustainable building materials Use of certified green building material |

End of Table 4

| Green Star | LEED | BREEAM | Green Mark | Green Building Index | BEAM Plus | IGBC Rating |
|--|---|--|-----------------------------------|---|--|---|
| Green Star Accredited Professional Commissioning and Tuning Adaptation and Resilience Building Information Commitment to Performance Construction Environmental Management | LEED accredited professional | Sustainable procurement Stakeholder participation LCC and service life planning Responsible construction practices Construction site impacts | Environmental Management Practice | Building user manual Accredited facilitator | Environmental Management Plan | Accredited professional Green building guidelines |
| <i>Management</i> | | | | | | |
| Sustainable Transport Operational Waste | Construction and Demolition Waste Access to quality transit Bicycle facilities Reduced parking footprint Green vehicles Light pollution | Construction waste management Operational waste Public transport accessibility Alternative modes of transport Maximum car parking capacity Travel plan NO _x emission Reduce light pollution | Green transport | Storage and collection of recyclables Construction waste management Public transport access Green vehicle priority Parking capacity | Local transport Air pollution during construction Noise during construction Water pollution during construction Light pollution Demolition waste reduction Waste disposal facilities | Low emitting vehicles Outdoor light pollution reduction Organise waste Management, post occupancy Handling of waste materials During construction |
| <i>Waste & pollution</i> | | | | | | |
| Microbial Control | Integrative process Regional priority | Safe access Hazards | | Workers' site amenities | Site design appraisal Neighbourhood daylight access Amenity features | Integrated Design approach Passive architecture Optimisation in structural design basic facilities for construction workers Universal design |
| <i>Other</i> | | | | | | |

There are two major types of green building tools: (1) assessment tools; and (2) rating tools. Assessment tools are used to make a choice among different alternative options, and rating tools could provide an indication to the public. There are many green building rating tools worldwide. LEED and BREEAM are the most widely used rating tools. Criteria such as energy and water consumption, indoor environment quality, land use and waste are listed in these rating tools. Green Star from Australia also follows a similar pattern about the key criteria. Some assessment tools focus on either one or two criteria separately (Table 3). This is similar to most of the green building rating tools, except Green star.

There are different incentives provided by governments to encourage development of green buildings in different regions. Tax incentives are provided in American, European and certain parts of Asia-Pacific region. In certain European countries, there are green tax incentives in personal income. In other European countries and many countries or regions in Asia and South Africa, practices of green buildings had been developed. Provision of incentives is well practiced (Olubunmi, Xia, & Skitmore, 2016). In addition, there are incentives on excise duties. However, there are fewer attempts on incentives in Australia. Furthermore, the focus of most available incentives is on renewable energy, but other criteria are not considered. Governmental funding is provided on the renewable energy and solar power. Moreover, incentives in European and Asian regions are widespread. Based on the previous literatures, tax incentives are considered as one of the successful factors to develop a successful green building market (Cansino et al., 2010; Hashim et al., 2016). However, effective incentive schemes are not available in Australia. Therefore, Australia should develop a tax incentive scheme. Olubunmi et al. (2016) stated that green building incentives are important in promoting green buildings. Furthermore, incentives on excise duties are also recommended. In terms of effectiveness, both external and internal incentives are important to promote green building, although it is unclear which one is more effective (Olubunmi et al., 2016). In most of the regions, many incentives are provided (Section 2). However, minimum incentives are provided by Australian government.

European and American countries have many regulations on constructing buildings. In the United States, it is mandatory to obtain a LEED or similar certification. In addition, support from governments is essential, because it would encourage developers to promote green building. However, such governmental support is not available in Australia. Although there are few requirements from State governments, there is no legal requirement to adapt green building features in building construction. According to Olubunmi et al. (2016), it is essential to enforce green building incentives and to establish proper government regulations. According to Olubunmi et al. (2016), there are limited resources to invest in green buildings, because of a lack of enforceable mechanism in developed and de-

veloping countries. There are no government regulations on green buildings (Section 3). If the diffusion of green buildings across Australia could be considered, majority of the green certified projects are from NSW (Section 3). Furthermore, NABERS certification in NSW is mandatory (Table 2).

In Australia, there are various assessment tools and rating tools. However, there is a lack of integration among these tools. Different State governments have different policies and various requirements in the use of these tools. Tools, such as NatHERS and BASIX are supported by state governments. Therefore, it is necessary to implement a policy to integrate various policies and requirements of different state governments in Australia. Based on main policies, each state government could implement plans to suit the requirements. Therefore, each state could equally contribute to the green building development. Green building requirements to building codes should be implemented as a mandatory requirement. Moreover, government could mandate a minimum green certification for new developments. These requirements could be extended to private building projects.

Conclusions

This study investigated various green building rating tools and incentive schemes around the world. In addition, green building rating tools and incentives in Australia were compared with tools used in other regions of the world. There are some differences between green building rating tools in Australia and other regions or countries: 1) there is a lack of mandatory criteria in Green Star used in Australia compared with LEED and BREEAM. Certification of green buildings could be obtained without achieving all the key criteria; 2) there is a lack of regulations and incentives to promote green buildings in Australia. Five different regions had adopted tax incentives, government mandates and incentives on excise duties to support green buildings. Based on the comparison, certain developments on green buildings could be promoted in Australia. Australia needs to develop governmental policies and regulations on green buildings, provide incentives to green building development, and enrich criteria in rating tools by adding costs. This paper could provide guidance to organisations such as Green building Council of Australia on the further development of in green building tools. In addition, State governments and federal governments in Australia could realize the necessity to promote tax incentives to encourage green building development. Furthermore, governing bodies should further consider a holistic approach to integrate policies.

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