How is the Energy Performance of Buildings Assessed in Australia? -A Comparison between four Evaluation Systems

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***Abstract*—Buildings consume a large amount of energy in Australia. To assess the sustainability performance, including energy performance, of buildings, Australia has developed several evaluation systems with the main ones being Green Star, NABERS, NatHERS and BASIX. Industry practitioners have a certain level of freedom to choose from these evaluation systems to evaluate the sustainability performance of their buildings. However, there is a lack of systemic comparison among these evaluation systems in general, and between the ways that the energy performance of buildings is assessed by these systems in specific. This study provides a systemic comparison between these four main evaluation systems regarding their approaches to assess the energy performance of buildings in Australia. The results show that these systems use different assessing methodologies, namely indicator-based or simulation-based methods, to assess different types of buildings based on data from different sources. These differences reveal the possibility of merging these existing systems to propose a new system that could better assess the energy performance of buildings in Australia.**

***Index Terms*—energy performance, green buildings, building rating system, Green Star, energy simulation, Australia**

I. Introduction

Sustainability considerations become increasingly important for the building sector [1, 2], which is a large energy and natural resource consumer in various countries including Australia [3]. Australia has committed to reaching net zero emissions nationally by 2050 mainly through promoting renewable energy. In 2016, the built environment-related energy consumption is 820 PJ, which is 48% of the total electricity generation. To assess the sustainability performance of buildings and provide guidance for sustainable retrofit, Australia has issued various evaluation frameworks, among which the systems of Green Star, NABERS, NatHERS and BASIX are the main ones and gain most popularity in Australia. However, the co-existence of these systems has gradually revealed two issues. Firstly, industry practitioners have a certain level of freedom to choose from these evaluation systems to evaluate the sustainability performance of their buildings [4]. Lacking a clear understanding of the similarities and differences of these systems, building owners usually choose the system that is better advertised than other systems rather than the system that is appropriate for their projects. Secondly, the lack of communications among these systems leads to segregation in the industry. Owners of buildings assessed by one system do not understand how their buildings would perform under another evaluation system, and thus still cannot accurately benchmark their buildings in the industry, which should be the aim of green building evaluation. These issues demonstrate the necessity of comparing the different evaluation systems to identify their similarities and differences. This study aims to partially respond to this gap of knowledge by comparing how the energy performance of buildings is assessed in Australia under different evaluation systems including Green Star, NABERS, NatHERS and BASIX.

II. Overview of the Four Evaluation Systems

As a non-profit organization, the Australian Green Building Council (GBCA) developed the Green Star Rating System in 2003, a voluntary assessment that requires at least 4 stars for formal certification [5]. The Green Star rating system covers a range of buildings including education, healthcare, industrial, multi-unit residences, accommodation, retail, public buildings and offices (offices, office interiors, office design and

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completion offices) [6]. The Australian Department of Environment and Heritage (DEH) was the first organization to publish the Australian National Building Environmental Assessment System (NABERS) [7], which was then taken over by the New South Wales Department of Environment and Climate Change. NABERS focuses solely on assessing the actual performance of existing buildings and can evaluate various types of buildings, including data centers, office buildings, hotels, shopping centers and houses [8].

The Nationwide House Energy Rating Scheme (NatHERS) is a star rating system that evaluates the thermal performance of a home [9]. Three certified software tools are used in NatHERS to obtain evaluation results, namely AccuRate, BERS Professional and FirstRate5. All of these tools are developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO) [10]. NatHERS was initiated in 1993 by the Australian and New Zealand Minerals and Energy Commission to help the public and the construction industry assess energy efficiency through the design and construction of buildings. With the spread of NatHERS, it began to contribute to the regulation of new building standards for some state and regional governments. The ACT first required a minimum four-star rating for new residential designs in 1995. BASIX is an assessment tool developed by the NSW Government. Similar to NatHERS, it focuses on houses rather than other types of buildings. BASIX evaluates three aspects of performance, namely energy, water and thermal comfort.

III. A General Comparison of the Four Evaluation Systems

As a non-profit organization, the Australian Green By examining the assessment guidelines and methods of these four systems, their similarities and differences are revealed which are summarized in Fig. 1

To summarize, Green Star and NABERS could assess various types of buildings and are totally voluntary while NatHERS and BASIX predominately focus on residential buildings and they are compulsory in certain situations. Green Star, BASIX and NatHERS mainly focus on the design and construction stage of new projects while NABERS only assess the actual performance of buildings based on the actual data at the operational stage. Regarding the assessment methods, Green Star and BASIX use indicator-based assessment systems while NatHERS use a pure simulation-based system. NABERS use an indicator-based system which is actually backed up by simulations and algorithms. Regarding the assessed aspects, Green Star has the most comprehensive coverage ranging from assessing indoor environment to innovation while NatHERS could only assess the energy performance [9]. BASIX and NABERS have a medium level of coverage assessing energy, water, etc.

Regarding the assessment procedures, Green Star and BASIX have similar procedures of assessing. In these two methods, building owners collect the relevant documents required for the evaluation and send the documents to the corresponding organization for assessment. Assessors then provide the overall score for the building by summing up the scores for the different aspects using a scoreboard. By contrast, in NatHERS, the assessment is completed by using one of the three energy simulation software developed by CSIRO, while for NABERS certification assessors need to evaluate the building based on both documents provided by building owners and site visits of the building.

Rating systems	Green star	NatHERS	NABERS	BASIX
Developer	Green Building Council of Australia (GBCA)	Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Australian Department of Environment and Heritage (DEH), now administrated by the NSW Department of Environment and Climate	New South Wales Government
Rating building type	Education Healthcare Industrial Multi-unit residential Accommodation Retail Convention centre/public buildings (pilots) office	Residential house	Data centre Office building Office tenancy Business hotel Shopping House	Single household Multi-family building Commercial buildings
Scope of application	Australia Nation wide	Australia Nation wide	Australia Nation wide	NSW
Requirement	Voluntary	Minimum 6-star rating for new constructed house and apartment.	Voluntary	Compulsory for all new state-of-the-art residential buildings and for renovations that are greater than $50,000 or involve new pools
Assessment method	Indicator based system	Simulation based system	Both indicator and simulation-based system	Indicator based system
Assessed aspects	Management Quality of indoor environment Energy Transportation Water Materials Use of land and ecosystem Pollution emissions Innovation	Energy	Energy Water Waste Indoor environment	Water Thermal comfort Energy
Strengths	Widest assessment range covering every stage of construction.	Enhanced simulation engine can provide scientific assessments.	Focus on the actual performance of buildings	Reduce the consumptions of water and energy and improve thermal comfort
Weaknesses	Long assessing period: 24 months	Assessment for energy only. File format limitation of software tools.	The certificate is only valid for one year, which means such assessment need to do annually.	Limited to residential buildings.

Figure 1. Comparison of green star, NABERS, NatHERS and BASIX.

These differences lead to the unique strengths and weaknesses of the systems. Green Star has a broad range and now it could also assess the actual performance of buildings. But when compared to NatHERS and NABERS in assessing energy performance, Green Star could be less accurate, as NatHERS assess energy using more nuanced energy simulations and NABERS directly assess the actual energy performance based on operational data.

IV. Comparison of the Energy Rating Approaches in Four Evaluation Systems

After examining the overall differences between the four systems, this study specifically investigates how the energy performance of buildings are assessed by these four systems. The results are summarized in Fig. 2.

These four systems have both similarities and differences in their approaches of assessing the energy performance of buildings. Specifically, both based on an

indicator-based system, Green Sar and BASIX adopt a similar decomposition approach to assess building energy, namely decomposing the building into components that directly influence energy consumption such as lighting, air-conditioning, and heating and cooling and assess their energy performance respectively. By contrast, NABERS only needs general information of the building such as net lettable area and computer numbers, as well as the actual energy bills of the building which could be all inputted into a specific algorithm developed by NABERS to generate the evaluation score for the building. Different from all these systems, NatHERS needs detailed information of the building including location and orientation, room zoning and building materials used, which all influence energy consumption indirectly and thus is needed in energy simulations. Therefore, as a simulation-based method, NatHERS needs more information about the buildings than other evaluation systems.

Rating systems	Green star	NatHERS	NABERS	BASIX
Considered aspect examples	• Building Envelope • Glazing • Lighting • Ventilation and Air-conditioning • Domestic Hot Water Systems • IT equipment • Appliances and equipment • Accredited GreenPower • Peak electricity • Demand reduction	• Location and orientation • Construction types • Size and function of rooms • Size and specification of openings • Building materials • Details of wall, roof and window types • Air leakage	• Air conditioning • Power to equipment (computer servers & tenant-installed signage) • Lighting • The fuel used by generator for tenants • lifts and escalators • air conditioning and ventilation • exterior lighting • generator fuel for public servicing	• Hot water systems • Heating and cooling system (fans, air conditioning, gas, electricity, etc) • Ventilation • Lighting • Pools and spas • Alternative energy sources (e.g. solar panel on the roof) • Other energy uses
Required data examples	• Separate switching illumination areas • Area of automatic illumination control system • Power density of the polymerized lighting • Total u-value of roof lights • Power of fan motor and pump • Thermal efficiency of water heater • Energy efficiency rate of package air conditioning equipment and refrigerant chillers • Promises to purchase greenpower	• Conductive heat (u-value) of windows • Solar heat gain coefficient of windows • Climate data • Size and function of rooms • Size and specification of openings • Building materials	• Net lettable area • Rated hours • Computer numbers • Energy consumed to be rated by the tenants: lighting, power to equipment, air conditioning, generator fuel • Heated swimming pool area • Number of function room seats • The number of trading days • Parking spaces	• Areas lid by LED or fluorescent • Total rated output of solar panels • Type of oven • Air-conditioner zoning • Poor heating systems and temperature settings

Figure 2. Comparison of approaches assessing energy performance in Green Star, NABERS, NatHERS and BASIX

In addition, Green Star and BASIX are mainly for new buildings based on design features, which could roughly reflect the energy performance of buildings in the operation stage but cannot accurately predict the actual energy performance, which is influenced by not only physical features of buildings but also occupant behaviors. Therefore, buildings with the same evaluation score in Green Star or BASIX could still have very different energy performance in the operation stage due to the various ways of operating the buildings. This situation happens to NatHERS as well, as energy simulation cannot perfectly describe occupant behaviour. By contrast, NABERS directly evaluate the actual energy performance of buildings in the operation stage, and thus could be more accurate than other systems.

V. Towards a Better System of Building Energy Evaluation

Based on the above comparison of the four existing systems, this study proposes a schematic design of a new system for evaluating building energy performance and the associated evaluation principals. The schematic design is demonstrated in Fig. 3. For the energy assessment of buildings at the design/construction stage, it is suggested that the current Green Star and BASIX system could draw on the systems of NABERS to propose algorithms to derive the star categories of the buildings. If the building owner would like to know more about the building energy performance, energy simulation could be then conducted to predict the energy consumption under the designed features of the buildings. The current green building evaluation system does not consider the embodied energy of the building material and components, which could be addressed by life cycle assessment (LCA) of the building based on the simulated energy consumption [11]. If the client would like to know the embodied energy of the building, LCA could be conducted. Therefore, the algorithm-based star category, simulation-based energy consumption prediction, and LCA-based embodied energy calculation provide three choices for the building owners, with the latter one providing more details to the building owners. For buildings at the design and construction stage, building owners could choose from these three choices according to their preferred level of details. For instance, a building owner could choose to only know the energy star rating of the building or choose to know both the star rating and the simulated energy performance.

When the building construction is completed, or owners of existing buildings would like to rate the energy performance of their buildings, it is suggested that building energy rating at this stage must rely on the actual operational data of the building. Energy ratings obtained at the design stage must be abolished and replaced by the energy ratings at the operational stage to reflect the real performance of the building. Currently, the NABERS rating system mainly uses an algorithm-based method and could provide ratings valid for only one year, which means assessors need to constantly assess the building and building owners need to assess their buildings every year. This is quite labour-intensive and time-consuming for both the assessors and building owners. It is suggested that an energy simulation component could be introduced in the rating to predict the energy performance of the building for another two years based on the actual data of the previous year, so that one assessment could provide energy ratings valid for three years. Again, building owners could have choices. They could choose to assess the building every year based on actual yearly operational data or choose to add the energy simulation component to have a rating valid for three years derived from one assessment.

This proposed new system of assessing building energy performance incorporates the merits of the existing systems of Green Star, NABERS, NatHERS and BASIX, and provides more flexibility to building owners

and generate more holistic and accurate information by incorporating embodied energy considerations and compulsory requirements to replace the design ratings with operation ratings of energy once the building is completed.

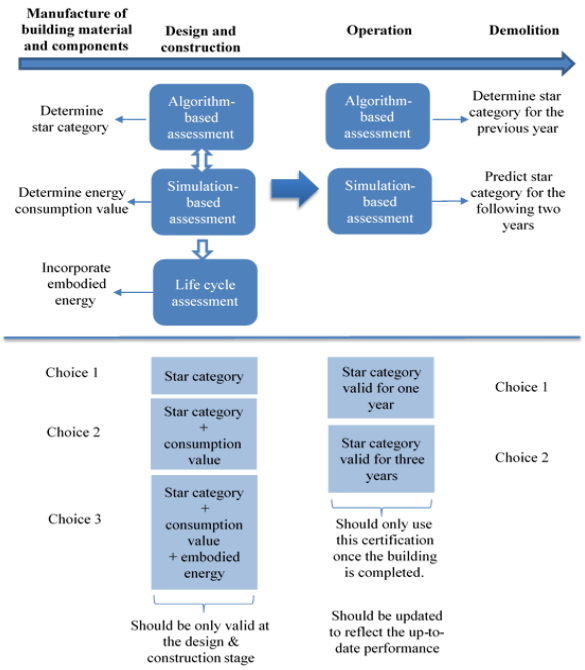

Figure 3. Schematic design of a new rating system for building energy performance

VI. Conclusion

This study compares four building sustainability evaluation systems used in Australia, including Green Star, NABERS, NatHERS and BASIX in general, and the ways that energy performance of buildings is assessed by these systems in specific. The comparison reveals that these four systems have significant differences in various aspects, such as the targeted building types, rating methods and assessed aspects. Their approaches to evaluating building energy performance are also different, even though there are some similarities. Based on this comparison, a schematic design of a new building energy system is proposed combining the merits of these existing system. The proposed new system not only provides more choices and flexibility for building owners, but also incorporates embodied energy considerations which capture building energy from a more holistic life cycle perspective. The proposed new system also provides a better benchmark for building owners. This study provides references for scholars studying building energy and sustainability, industry practitioners in the building sector, and relevant organisations and policymakers engaging in building sustainability and energy evaluations.

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