Optimising housing assessment to drive low carbon energy efficient housing upgrades

Prepared by
RMIT University

for
Department of Environment, Land, Water and Planning

January 2023

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What's next...

Acknowledgement of Country

RMIT University acknowledges the people of the Woi wurrung and Boon wurrung language groups of the eastern Kulin Nation on whose unceded lands we conduct the business of the University. RMIT University respectfully acknowledges their Ancestors and Elders, past and present. RMIT also acknowledges the Traditional Custodians and their Ancestors of the lands and waters across Australia where we conduct our business.

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Executive Summary

The Department of Environment, Land, Water, and Planning (DELWP) contracted RMIT University to identify, from the literature, key principles to underpin housing energy assessment (variously known as energy rating tools) that produce results that are suitable for transacting information about housing condition and informing retrofit actions to decarbonise housing. The work was undertaken in four main parts. First, a literature review was undertaken to inform the key criteria relevant to the construction and implementation of housing energy assessment. Second a selection of assessment tools was chosen for detailed analysis, to provide an understanding of how the key criteria are met in actual existing conditions across different jurisdictions. Third, a review was undertaken of housing stock condition data to help inform housing assessment tool options. Fourth, the above three steps were cross-analysed to provide a set of practical implications for design parameters for an optimised housing assessment for Australia.

The literature review shows that a lack of clear, independently verified, reliable and consistent information about dwelling energy performance and opportunities for improvement is a barrier to retrofit. Households may not know what is required, who to trust, or what would be the benefits of particular actions, or how to prioritise and specify improvements. Also, prospective purchasers or renters may not know what the bills are likely to be for heating and cooling, and what improvements might be required, or how liveable the dwelling will be. Market failures that exist in the absence of these energy assessments include principal-agent problems (where retrofit investors and bill payers are not aligned in their needs and motivations relating to retrofit) and information asymmetry (where information is not held transparently and equally about property condition and retrofit affecting decision-making e.g. householders not understanding retrofit technologies and services and therefore having difficulty in making decisions about retrofit options and trusting suppliers).

Across the wider academic literature there is broad support for the concept and role of house energy rating (or similar) assessments to help address such market failures (Attanasio et al., 2019; Crawley et al., 2020; Doyon & Moore, 2020; Fuerst & Warren-Myers, 2018; Geller et al., 2006; Jalas & Rinkinen, 2022; Kok & Kahn, 2012; von Platten et al., 2019; Wiese, Larsen, & Pad, 2018). Hence:

- A well-designed energy performance housing policy provides a strong rationale to prioritise carbon abatement activities.
- Housing energy assessment plays an important role in guiding retrofit to meet carbon emission reduction targets.
- In order for housing energy assessment information to be able to be transacted across households, property industry actors, and building industry actors, it must provide accessible, independently verified, and reliable information about property condition and retrofit options.
- To drive uptake of housing energy assessment information, it must be consistent, standardised, objective, trustworthy, and independently validated by an expert. This is to mitigate risks of the whole enterprise being undermined by assessments that overstate performance or utilise poor quality data that is not trusted or useful.

Internationally, requiring energy assessments of homes at point of sale and lease is a commonly used policy to overcome barriers to upgrades to homes. Important characteristics include:

- Trained and accredited assessors as key to accurate assessments and trust in the program. This needs to be supported by effective quality control and transparent standard methodologies.
- Public disclosure of an overall housing assessment when advertising for sale and lease, fines for non-disclosure, and assessments held on a public database so they can be used for broader policy analysis.

- Assessments that are easy to understand by the general public, comparable between housing of similar types and locations, repeatable (not changing between assessors), reasonably representing home energy performance supporting the overall policy objective (which includes energy cost, carbon, and comfort considerations), and inclusion of recommendations for improvements.
- It is important to ensure assessments are tested in the field in a range of building types and climate conditions to ensure assessments are useful and accurate before implementation.

This study also examined the evidence on costs and benefits of housing assessments. Findings include:

- Having housing assessments that drive upgrades is more important than minimising the cost of assessments.
- The comparability, legibility, and wide acceptance of assessments is widely considered important in fostering action. There is a value to energy efficient homes, incentivising upgrades. Careful program design is essential to realise this potential.

The housing stock review reveals important gaps in our knowledge of the condition and retrofit potential of Australia's housing stock. This stems from a lack of sufficiently detailed data to represent the diverse stock and the results of previous renovations and retrofit for energy efficiency in particular. In the absence of an integrated and sufficiently detailed picture of the stock condition, policy ambitions on climate change mitigation and on housing standards and a set of broader health and wellbeing objectives all remain at risk of being either ineffective or inefficiently configured. A housing assessment rating, administered broadly and consistently, is a means to provide the necessary information to address this risk.

The above steps fed into a set of practical implications which we present as four design requirement objectives for an optimised housing assessment for Australia. This is discussed in Section 4 below. A summary is included in the following simple table:

Design requirement objective	Key requirement
Accurate and Holistic The assessment must reasonably assess what it intends to assess.	Reliable and certified by an expert assessor, seen as highly regarded, and accuracy not in question.
Robust and Consistent The process of implementing the assessment must demonstrate integrity including both the way the assessment is undertaken and the results it produces.	Moderated and reliable output, i.e., repeatable and with low variance.
Applied and Clear The assessment must be applied and integrated into the sectors that it intends to influence and be able to be used, easily, by the people involved.	Produces a legible, accessible, intuitive rating summary page and symbol that has widespread recognition (like appliance labels).
Transparent and Adaptive The process must build trust with key stakeholders and reflect the changing context associated in relation to housing.	Open data and algorithm, with regular upgrades/updates.

An optimised housing assessment system would be part of a comprehensive scheme of mandated assessments to provide for a comprehensive dataset and for widescale uptake and engagement with the information. Much like the well-regarded appliance labelling schemes in Australia, the fact that retailers are mandated to provide labels on the included appliances ensures widespread familiarity. To engender trust, it is essential to have trained assessors responsible for the assessments, who validate their observations onsite. This is also essential in order to provide the necessary robustness so that housing assessment data can be used in transactions, for example at sale or lease. It follows that housing assessments must be verifiably accurate and independent, consistent, and accessible to all stakeholders.

1 Identifying the issues

Key findings

- A well-designed energy performance housing policy provides a strong rationale to prioritise carbon abatement activities and includes transparency and accountability.
- Housing assessment plays an important role in encouraging retrofit to meet carbon emission reduction targets.
- In order for housing assessment information to be able to be transacted across households, property industry actors, and building industry actors, it must provide accessible, independently verified, and reliable information about property condition and retrofit options.
- To drive uptake of housing assessment information, it must be consistent, standardised, objective, trustworthy, and independently validated by an expert. This is to mitigate risks of the whole enterprise being undermined by assessments that overstate performance or utilise poor quality data that is not trusted or useful.

Australia is committed to 43 per cent carbon emission reduction below 2005 levels by 2030 and net-zero carbon emissions by 2050. Action towards a low carbon future is necessary for planetary survival as we know it, and it can also support social equity and improve the wellbeing of Australians, particularly when applied to housing (Barrett, Horne, & Fien, 2021; Moore et al., 2017). A major benefit of upgrading the energy performance of homes is that reducing carbon emissions also directly reduces energy costs and improves comfort. The outcome of well-designed energy performance housing policy is that there is no net cost of abating carbon – the cost is more than offset by reduced energy and health costs. This provides a strong rationale to prioritise these carbon abatement activities.

To reduce carbon emissions, enhancements to the energy efficiency of housing will be needed through more stringent building and appliance standards and widespread energy efficiency retrofit. Independent, verified information about housing emission performance and what needs to be done at the individual dwelling level are necessary to provide certainty for industry and stimulate this activity, thereby building a market.

Residential housing is a primary contributor to Australia's greenhouse gas emissions (DCCEEW, 2022; IEA, 2022). Australia had 10.8 million dwellings in 2021 (ABS, 2022) and the population is projected to increase by 3.6 million people by 2032 (Australian Government, 2022), expanding housing needs across the short- to long-term. At the same time, Australians are currently experiencing a rising cost of living crisis driven by poor quality and performing housing, including rapidly increasing energy costs and resultant energy bills, leading to increasing instances of energy poverty and energy vulnerability across the community. As a result, housing quality and energy efficiency retrofit are issues of public health and equity and require a national response.

Previous research found that: '7.3 per cent of Victorian households (or 180,000 households) ha[d] persistent bill payment difficulty, and 1.8 per cent of Victorian households (or 45,000 households) are persistently unable to heat their homes' (VCOSS, 2018, p. 4). Evidence from around the world has shown time and again that improving housing energy efficiency provides a cost-effective opportunity towards achieving a net-zero target and addressing challenges such as cost of living (Boardman et al., 2005; Daniel et al., 2021; Garrett et al., 2021; Sherriff, Martin, & Roberts, 2018; Willand, Maller, & Ridley, 2019). Delivering large-scale deep retrofit for existing housing will need to be a key strategy if Australia is to address these wider challenges across the short- and longer-term.

The housing energy efficiency retrofit industry is situated within the broader building and home renovation industry. Industry bodies and suppliers have developed expertise over recent decades and this expertise could be leveraged using effective policy instruments to scale-up retrofit. While housing in Australia is in variable condition, upgrades such as draught-proofing; adding (or topping up) ceiling, floor and wall insulation; improving window performance; and improving the efficiency of appliances, have been shown to be both cost-effective and critical in contributing to Australia's commitment to a zero-carbon future by 2050 (BZE, 2013; DISER, 2021; Fox-Reynolds, Vines, Minunno, & Wilmot, 2021; Sustainability Victoria, 2019). Despite the benefits of retrofit, the percentage of the existing housing stock that is engaging with deep retrofit remains lower than that required to meet the needs for a sustainable and liveable housing stock (Fox-Reynolds et al., 2021).

A range of factors have slowed retrofit uptake, including the various interactions between housing stock, tenure, the socio-economic characteristic of households, the availability of trusted information, and market dynamics. Approximately one third of houses in Australia are rental housing where the onus of retrofits and upgrades largely rests with the landlord (social, institutional, private or commercial) and where principal agent or split-incentive problems are a barrier to upgrades (Lang et al., 2022). For the remaining two-thirds of housing, retrofits and upgrades rest with the homeowner. All households experience a range of barriers such as having competing objectives, being under-resourced, and finding it difficult to navigate fragmented and variable advice from different stakeholders for their specific housing needs. Households may not know how long they will be staying in a dwelling, and an information asymmetry between consumers and suppliers can result in a lack of trust of suppliers and consequent inaction or substandard upgrades.

A key policy instrument that has been used worldwide to drive demand for energy efficiency retrofit across both rental and owner-occupied housing and to counteract market failures is accessible, independently verified, and reliable information about property condition and retrofit options to inform optimised investment in upgrading housing stock (European Commission, 2015; Horne, 2018; Hurlimann et al., 2018; International Energy Agency, 2013; IPEEC, 2014, 2019; Moore, Berry, & Ambrose, 2019).

Globally, the leaders in independent energy assessment of individual existing dwellings are in Europe, where since 2002 a binding Energy Performance of Buildings Directive has required member states to institute assessments of buildings so that independently verified condition data is available at times of sale or lease (European Commission, 2022; Panteli, Duri, Olschewski, Klumbyte, & Delft, 2021; Zuhaib et al., 2022). Typically, these assessments are required to be conducted by an accredited assessor. The aim of this policy approach is to provide reliable and comparable information on home energy performance which has been found to drive home upgrades and improve the value placed on improving home performance (Myers, Puller, & West, 2019).

In the United Kingdom (UK), home energy ratings are considered as integral to the delivery of policies associated with the energy performance of the UK housing stock. This includes developing, implementing and tracking policies to support vulnerable groups (Brown et al., 2021). Increasingly such tools are contributing to larger datasets on overarching housing condition and performance which is helping to guide housing and retrofit policy making and programs (Brown et al., 2021).

1.1 Aim and scope

The Department of Environment, Land, Water, and Planning (DELWP) contracted RMIT University to identify, from the literature, key principles to underpin housing energy assessment (variously known as energy rating tools) that produce results that are suitable for transacting information about housing condition and informing retrofit actions to decarbonise housing. The work was undertaken in four main parts. First, a literature review was undertaken to inform the key criteria relevant to the construction and implementation of housing energy assessment. Second a selection of assessment tools was chosen for detailed analysis, to provide an understanding of how the key criteria are met in actual existing conditions across different jurisdictions. Third, a review was undertaken of housing stock condition data to help inform housing assessment tool options. Fourth, the above three steps were cross-analysed to provide a set of practical implications for design parameters for an optimised housing assessment for Australia.

Housing energy assessments are known variously as 'home energy ratings', or a combination of words thereof. In this report the term 'housing assessment' refers specifically to assessments designed to inform energy and carbon performance in the context of the need to accelerate decarbonisation of housing stock through retrofit. A key question is how to ensure an effective assessment that meets cost-effectiveness and productivity objectives and engenders action to decarbonise housing. Clarifying upfront the purpose and desired outcomes of an assessment is critical, as there are a range of reasons why a home might be assessed.

Key parameters of housing assessment are reliability and comparability. Realisation of these parameters allows households to compare dwellings and performance. Another key parameter is efficacy, such that each assessment can be used in legal transactions and public disclosure, for example, between buyers, renters, and policy makers. Achieving efficacy requires a consistent, standardised, objective, trustworthy, transparent, validated approach. Housing assessments that overstate performance, or produce poor quality databases, undermine trust and utility of the whole system.

In cases where households do not want to share assessment results and they wish to consider subjective data such as personal usage, different retail energy costs, and behaviours, to predict and reduce energy costs, emissions or comfort, there is little incentive to overstate performance. However, it is still important that the rating is consistent, standardised, trusted, transparent, and valid.

Bringing large numbers of individual housing assessments together into a database provides the potential to inform policy and program design, for example, to assess outcomes or design parameters to target particular dwellings, locales, households, technologies, tenures, and typologies, as examples. This requires a consistent, standardised, objective, trustworthy, transparent, validated approach to each assessment to preserve the quality of the dataset.

There are numerous benefits from generating an independent, accurate, privacy protected database of housing assessments. Australian housing presents a diverse set of conditions (e.g. tenure, typology, size) including also a wide range of climatic conditions. Each home is inevitably altered over the years, and seemingly minor variations can make noticeable differences to energy demand and performance, even between otherwise identical dwellings. The enthusiasm for home renovation means that homes with outwardly similar characteristics can have very different energy performance. If accurate and comparable data is available nationally, then approaches to cost-effectively improve stock can be more easily developed. Also, a reliable understanding of energy performance means the outcomes of building energy policy can be monitored over time to determine if the proposed benefits are being achieved.

The vast majority of applications of housing assessments require them to be able to be transacted across households, property industry actors, and building industry actors. In this case, they must provide accessible, independently verified, and reliable information about property condition and retrofit options. The only other case is that of the ‘self-help’ tool where property owners or renovators can choose information that they wish to use to inform retrofit decisions. This includes resources such as the Your Home guide in Australia, or the Vermont Home Energy Profile in the United States of America (US). In such cases, users would still prefer advice to be independent, accurate and verified.

Possible methods for housing assessments therefore range from a home occupier self-checklist through to dwelling modelling, and/or use of a range of actual monitored performance data (e.g. utilities, temperature), and then on to actual onsite observations of technologies and conditions (Al-Addous & Albatayneh, 2020; Cho & Kim, 2019). **Figure 1** shows the spectrum of approaches used across the European Union (EU) (Crawley et al., 2020). On the left is an approach based purely on calculations or basic design information, with no real measured data. On the right is an approach based on measurement, with limited interpretation. The points in between represent various combinations between those two extremes.

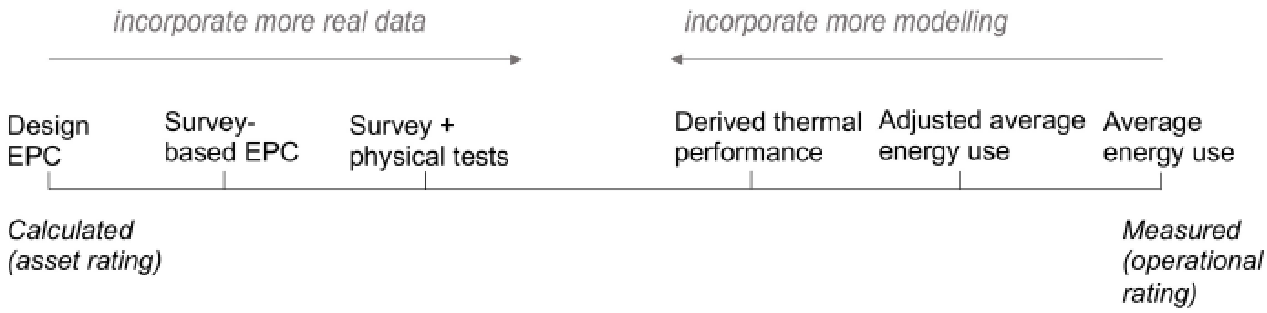

Figure 1. Spectrum of rating methods used in EU member states (Crawley et al., 2020, p 2).

Often housing assessments use mixed methods. As an example, the EnerGuide System in Canada sets an Evaluation Procedure that includes field audit methods, standardised data collecting forms (including a house observation checklist, software analysis tools, and a rating label) and a tailored homeowners’ report (Parekh et al., 2000). The evaluation includes:

- Pre-evaluation: the energy evaluator conducts a telephone interview to obtain information about the property, including the number of residents, current problems, renovation plans, house description and construction year, as well as the heating system and fuel costs.
- On-site house evaluation: the energy evaluator gathers information on the building structure and site, the building envelope, mechanical systems, building area and volume, building orientation, and other key information, as well as opportunities for energy savings, retrofit work constraints, health and safety issues, and structural concerns. The assessor also employs a blower door test to determine the rate of air leakage, as well as a smoke pencil to find air leakage locations and record evidence of combustion spills.
- Energy modelling and analysis: the evaluator uses the most up-to-date software to produce the rating.

The scope of the current study is set by the starting parameter that the housing assessment outcome/rating must be able to be transacted across households, property industry actors, and building industry actors, and must provide verified information about each specific individual dwelling so that dwellings can be compared, and upgrades can be specified. In this case, they must provide accessible, independently verified, and reliable information about property condition and retrofit options. Therefore, tools that are solely designed to inform retrofitters are outside this scope. Indeed, there are several approaches that fall outside out of the scope. For example, average (mean) energy use measured in bills, doesn't meet the test of the starting parameter. There is only a small range of approaches that could satisfy our criteria and they all require onsite verification and expert assessment coupled with supplementary data sources of design of appliances.

To drive uptake of housing assessment information, the assessment must be consistent, standardised, objective, accessible, trustworthy, and independently validated by an expert. This is to mitigate risks of the whole enterprise being undermined by assessments that overstate performance or utilise poor quality data that is not trusted or useful.

2 Review and analysis of housing assessments

2.1 Overview of housing assessments worldwide

This section focuses on the development and objectives of housing assessments to demonstrate distinctions in objectives and outputs and consequent approaches. Additional details of the design are included in section *2.3 Analysis of selected assessment tools*.

2.1.1 Europe and North America

Key findings

Requiring energy assessments of homes at point of sale and lease is a commonly used policy to overcome barriers to upgrades to homes. Important characteristics of these policies follow.

- Trained and accredited assessors are key to accurate assessments and trust in the program. This needs to be supported by effective quality control and transparent standard methodologies.
- Public disclosure of an overall housing assessment when advertising for sale and lease, fines for non-disclosure, and assessments held on a public database so they can be used for broader policy analysis.
- Assessments should be easy to understand by the public, be comparable between housing of similar types and locations, be repeatable (not changing between assessors), reasonably represent home energy performance supporting the overall policy objective (which includes energy cost, carbon and comfort considerations), and include recommendations for improvements.
- It is important to ensure assessments are tested in the field in a range of building types and climate conditions to ensure assessments are useful and accurate before implementation.
- The program is regularly evaluated to ensure the outcomes are being achieved in homes and new technologies are included in the assessments.
- Assessment programs may be supported by grants to reduce the cost of assessment, subsidise upgrades, and encourage assessors to undertake training, all with an equity lens.

Housing assessment has emerged alongside minimum performance regulations in many regions of the world, and dates back to the 1960s in jurisdictions across Europe and North America (Berry & Marker, 2015; International Energy Agency, 2013; Kordjamshidi, 2011). Since the 1990's there has been an increasing number of jurisdictions introducing and/or revising assessment tools aimed at existing housing.

A notable example is the development of Energy Performance Certificates (EPCs) in Europe, which have been used as part of mandatory disclosure regulatory requirements to provide information about a dwelling at point of sale or lease. The main intent of such regulation and assessment is to address key barriers to housing upgrades including information asymmetry (Brounen & Kok, 2011; Economidou et al., 2020; Fuerst et al., 2013; Fuerst & Warren-Myers, 2018; Geller et al., 2006; Hårsman, Daghbashyan, & Chaudhary, 2016; Kok & Kahn, 2012). Specifically, EPCs were developed to provide information on dwelling quality and performance to guide prospective buyers and renters in their decision-making process, as well as to drive demand for energy and sustainability retrofits (Economidou et al., 2020). As a result, the assessment design allows comparison of a building's energy performance, and comparison against reference values such as minimum energy performance requirements, and provides recommendations for cost-optimal or cost-effective upgrades (European Commission, 2022).

EPCs are currently among the most important sources of information on the energy performance of the EU's building stock (BPIE, 2010). In 2002, the European Union (EU) introduced the Energy Performance of Buildings Directive, which required the use of EPCs throughout the EU. The Energy Performance of Buildings Directive is the EU's major legislative tool for improving building energy efficiency for new and existing buildings; this is a broad framework with specific performance requirements set by each individual jurisdiction. EPCs are intended to reduce energy use and carbon emissions by providing information that can be utilised to make better decisions (Bio Intelligence Service, Ronan Lyons, & IEEP, 2013). The EPC is a legal document generated during certification, typically by an accredited assessor via an in-home assessment. The assessment includes an energy performance rating ranging from 'A' (very efficient) to 'G' (very inefficient). While the EU sets a broad framework for how an EPC should be developed and operated, it is left to each individual jurisdiction to develop their own method and approach, informed by both their own local context and benchmarks, as well as wider EU goals. This has resulted in variances of calculation, assessment methods and communication of outcomes, making comparison between assessments of different EU jurisdictions difficult (Semple & Jenkins, 2020). When a building is advertised for sale or rent, the EU Commission mandates that certifications form part of all advertisements (Economidou et al., 2020). Certificates have a validity of 10 years and must provide an overall energy performance rating for the dwelling and provide recommendations on how to improve existing energy performance (Economidou et al., 2020).

The principal purpose of EPCs is to serve as a resource for building owners, occupiers, and real estate professionals. However, importantly, the data is also able to be used at a larger scale in extensive databases of housing condition, to help guide policy making and support programs for retrofit (Brown et al., 2021). There is variation in the implementation of EPCs across the EU and the wider impact or influence they are having on the housing sector (Andaloro et al., 2010). For example, Zuhaib et al. (2022) note in their research that Denmark is a front runner in relation to having a well-developed EPC regime, Portugal and Greece are developing EPC regimes, and Poland and Romania have more recently been involved in EU Directives, and are late adopters in EPCs.

EPCs were introduced in the UK in 2007, as the rating tool to be applied whenever a property is built (separate to minimum standards), sold, or rented. Over 23.7 million UK EPCs have been lodged including more than 19.1 million certifications undertaken on existing dwellings from 2009 to 2021 including repeat certifications (Figure 2). There are currently around 24.7 dwellings in the UK although it is unclear what percentage of existing dwellings have an EPC. The EPC is embedded in real estate processes and backed by policy instruments in line with their purpose: 'to provide accurate and reliable assessments of dwelling energy performances that are needed to underpin energy and environmental policy initiatives' (UK Government, 2021). For example, an EPC must be produced by an accredited assessor, obtained before a property is marketed, and provided at point of sale or rental. If an EPC is not attained when needed, a fine may be issued (UK Government, 2022a). It is easy to find the EPC of another property through a prominent search on the UK government website, thereby supporting the intent for households to be able to compare the energy rating of dwellings and make informed decisions (UK Government, 2022a).

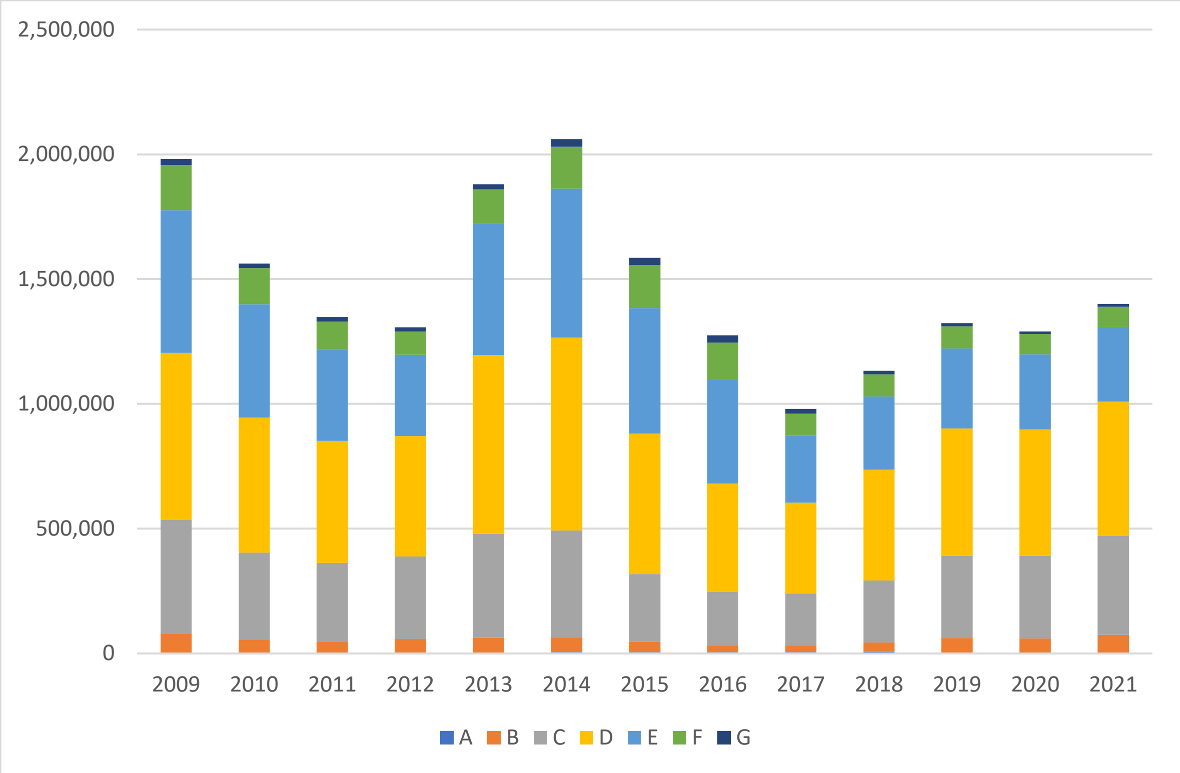

Figure 2. EPCs generated for existing dwellings in the UK since 2009 (UK Government, 2022b).

Several jurisdictions are reviewing their assessment designs in response to emissions reduction initiatives, new technologies, and improved housing performance targets. For example, in May 2022, the Building Research Establishment in the UK announced that it would 'improve and modernise' the methodology used to measure the energy and environmental performance of housing, which is used to inform EPCs and to show compliance with the energy conservation requirements of Building Regulations (BRE, 2022). The updated methodology will be 'better suited to modern dynamic technologies' including heat pumps, renewable energy technologies and smart technologies (BRE, 2022). It is not just the calculation methodology which is evolving but also the assessments themselves. For example, Flanders, Belgium, introduced a revised version of the EPC certificate in 2019, adding A+ to the highest performing score for dwellings that produced more energy than they consumed (Taranu, Verbeeck, & Nuyts, 2020).

In North America, policy makers and researchers identified that a lack of clear and reliable information about the energy performance of a dwelling was a key barrier to homeowner investment in home energy upgrades or improvements. In response, a number of programs and support were developed including the voluntary Home Energy Score program which was launched in 2012 (US Department of Energy, 2021). The guiding principles of the tool are that it is credible, reliable and replicable, transparent, easy to understand, affordable and subject to effective quality control. The Home Energy Scoring Tool is an asset-based assessment including assumed occupant profiles that estimates a home's current energy-use and evaluates the impact of implementing recommended energy efficiency improvements. Home assessors are accredited and must meet training and quality assurance requirements (US Department of Energy, 2022). The Home Energy Score rating includes information on insulation levels and heating equipment efficiencies, but it excludes thermostat settings, appliances, and plug loads because the total energy used to operate these components varies greatly based on occupant behaviour. In the first year of the program 7,000 assessments were undertaken (Glickman, Kappaz, & Khowailed, 2014), and almost 175,000 were completed as of January 2022 (US Department of Energy, 2022). The Home Energy Score is a standardised consistent approach used in the US to support a variety of mandatory minimum house standards, house performance disclosure, voluntary and subsidised assessment and retrofit programs.

The Department of Natural Resources Canada launched the EnerGuide for Houses Program (EnerGuide) nationally in 1998 to promote energy efficiency upgrades of existing housing (Parekh, Mullally-Pauly, & Riley, 2000). EnerGuide is an official 'mark' of Natural Resources Canada and used for rating and labelling consumer items. Key development successes include development of technical guidelines, audit procedures, energy evaluation software and homeowner reports, program implementation and tracking procedures, quality control procedures, auditor training courses, and, pilot testing in three distinct housing markets (Parekh et al., 2000).

Grants are available to support both home assessments and upgrades, with the grant linked to the level of improvement generated by the upgrade. Energy advisors (otherwise called home assessors or auditors) are considered the backbone of the program. Further grants are available to encourage auditors, particularly from underrepresented groups to join the program (Natural Resources Canada, 2022). The brand is described as having 'an excellent brand-name reputation with homeowners' (Parekh et al., 2000, p. 3). The framing of an energy efficient home includes the benefits of being 'comfortable, healthy, environmentally friendly and cost-effective' (Government of Canada, 2022b), all of which are incorporated into the assessment by also including minimum ventilation rates for comfort and health (Parekh et al., 2000).

The EnerGuide rating undertaken by a trained auditor, includes an asset-based assessment and standard operating conditions for comparison of homes in the same region, as well as the collection of specific household operating conditions to inform the recommendations (Government of Canada, 2022a). One evaluation found customers installed about two-thirds of recommended measures resulting in the reduction of energy use by 10 per cent to 15 per cent annually in houses that were retrofitted. Part of the success of the implementation of the program is attributed to the extensive process taken to design the program and pilot testing in distinct housing markets (Parekh et al., 2000). The pilot testing occurred between 1995 and 1997 and assessments were undertaken on 350 dwellings across three regions, which provided feedback into revisions and improvement of the program (including revising the name) and assessment approach (addressing a disconnect between modelled and actual energy performance of up to 90 per cent).

2.1.2 Australia

Key findings

- Requiring energy assessments of homes to be disclosed at point of sale and lease has been successfully used in the ACT to improve home energy performance.
- There has been long term interest, and policy work and consultation on a national program, which has found that such a program would generate significant benefits. This analysis found that there was a valid case for government intervention, and that this would be welfare enhancing for society.
- It is critical that disclosure is trusted. Self-assessment of home performance does not meet this requirement. It does not provide the required rigor, verification, quality control, and accuracy to deliver the policy outcomes of driving upgrades.
- Benefit is maximised by requiring assessments delivered by accredited assessors that do not require full plan drawings of the home but do include an on-ground assessment of the home thermal performance and main installed home appliances. Opt-out options to assessment, risk the program not delivering benefits due to the incentive to opt out.
- It is important that disclosure of a housing assessment is required when homes are advertised, that advertisements are displayed prominently and clearly, and that the customer is not required to request that a rating be supplied.
- It is important to support the program with public awareness raising of the benefits of the program.

While Australia has been described as having limited experience of housing assessment, one of the longest running housing performance assessment and disclosure programs globally has been in operation in Australian Capital Territory (ACT). Mandatory disclosure of a home's thermal efficiency rating at point of sale or lease has been in place since 1999 and 1997 respectively (Berry, Marker, & Chevalier, 2008; Berry, Moore, & Ambrose, 2022; Fuerst & Warren-Myers, 2018; Gabe, 2016). The scheme, which aims to make information about a property's energy efficiency public, is separate from the National Construction Code and the ACT's state planning and building approvals processes (O'Leary, 2012). There is no legal minimum level of rated energy efficiency for existing homes, as there is for new buildings. Importantly, higher rated properties have been found to be associated with relatively higher property values, which suggests the influence of the assessment on market valuation and decision-making (Department of the Environment Water Heritage and the Arts, 2008; Fuerst & Warren-Myers, 2018).

There has been longer interest and substantial analysis of disclosing the energy, greenhouse gas, and water performance of existing homes in Australia. In 2003, the National Framework for Energy Efficiency's Building Implementation Committee on behalf of the Council of Australian Governments (COAG) Ministerial Council on Energy, agreed to investigate energy performance disclosure for residential buildings. In 2009, the COAG Ministerial Council on Energy introduced the National Strategy on Energy Efficiency which proposed mandatory disclosure of building energy, greenhouse gas, and water performance at the point of sale or lease for residential properties (Council of Australian Governments, 2009; Department of Climate Change and Energy Efficiency, 2012).

An analysis of Mandatory Disclosure of Residential Building Energy, Greenhouse and Water Performance: Consultation Regulation Impact Statement, was released and consulted on in 2011, finding disclosure would generate substantial benefits (Allen Consulting Group, 2011).

Some of the major findings of this analysis include:

- There was a case for intervention and there was a valid case for government intervention, which would be welfare enhancing for society.
- Benefit was maximised by requiring assessments delivered by accredited assessors that do not require full plan drawings of the home but do include an on-ground assessment of the home thermal performance and main installed home appliances.
- Opt out approaches to assessment, risk the program not delivering benefits due to the incentive to opt out.

In parallel, in 2009, the Queensland State Government established the *Building and Other Legislation Amendment Bill* (2009) (Queensland Government, 2009), which introduced a mandatory disclosure requirement to state the environmental features of dwellings for sale in Queensland via a 'Sustainability Declaration' (or checklist). The regulation came into effect on 1 January 2010 and compelled all residential sellers to complete a self-declaration of their dwelling's environmental and social sustainability features in four key areas: energy, water, safety, and access (Bryant & Eves, 2012). The Sustainability Declaration was criticised by a range of stakeholders for its limitations including that some sellers were leaving sections of the declaration blank where it did not result in a good outcome for the dwelling and concerns over the reliability of information provided, resulting in a lack of trust (Wong et al., 2016). The checklist did not meet basic criteria for rigor, verified and independent accuracy required for use in property transactions. The regulation was discontinued in mid-2012.

In considering the case for repeal (Treasury (Cost of Living) and Other Legislation Amendment Bill 2012 (Qld): Repeal of Sustainability Declarations Provisions) the State of Queensland noted two reports regarding the effectiveness of sustainability declarations. The Winton Sustainable Research Strategies Report, provided to the previous Government in 2010, based on a survey of 900 Queensland homeowners and potential homeowners, found that, when prompted, just over half of the respondents (54 per cent) claimed awareness of sustainability declarations. However, 91 per cent of respondents said that having information about sustainability features was useful.

The Winton (2010) report found that 34 per cent of people said they would pay up to 10 per cent more if a house contained a number of sustainability features (with more younger than older people prepared to do so). The sustainability declaration was used by 21 per cent of buyers for comparison purposes; 54 per cent of sellers found the sustainability declaration quite or very easy to complete but 22 per cent had some difficulty completing it (Winton, 2010). Remarkably, only 71 per cent believed the information they gave was quite, very or extremely accurate and 20 per cent of respondents said they left it blank, not being sure what was needed (Winton, 2010). Of the sellers, 77 per cent installed sustainable design features before putting the home on the market (usually insulation) and 57 per cent thought it increased the resale value at least a little (Winton, 2010).

A 2012 Queensland University of Technology Research Paper (Bryant & Eves, 2012), assessing the initial impact of sustainability declarations on home buyer decisions in the first year of operation, found seller awareness of needing to provide a sustainability declaration was poor (with 65 per cent in Brisbane not being aware) and few forms were fully completed by sellers. It also found that 20 per cent or less of potential buyers asked for the declaration during the transaction process, suggesting low trust and/or awareness. Discussions with a variety of industry participants also suggest that because sellers could be liable to compensate buyers for inaccuracies in the declaration, few forms were fully completed – thus compounding the lack of interest in them by buyers (Bryant & Eves, 2012).

In repealing the legislation, transitional provisions sought to preserve the rights of buyers who incurred a loss through a false or misleading sustainability declaration, to continue to be able to seek compensation. It was also noted that a key measure of COAG's National Partnership on Energy Efficiency is the phasing-in of mandatory disclosure of residential building energy, which remains pending in 2022.

Victoria released the voluntary Residential Efficiency Scorecard in 2017 to provide a rating of how energy is used in a home (State Government of Victoria, 2022). The program aims to provide a robust rating of a home's energy performance and provides suggestions to improve the rating. Accredited and trained assessors visit a home to conduct an assessment and discuss the needs of the household. The assessor provides upgrade advice and issues a certificate with the home's energy, greenhouse gas, and comfort ratings and recommendations on how to improve the assessment (DELWP, 2022b). The cloud-based tool is used to collect objective data on room sizes, construction materials, window type, placement and furnishings, insulation, hot water system, heating, cooling, lighting, and any renewable energy sources. The Scorecard was trialled nationally at the start of 2021 to test whether it was fit-for-purpose in all jurisdictions. The trial was successful and in August 2021, all jurisdictions and the Commonwealth approved a national rollout, which will be undertaken as a four-year project to mid-2025. The national assessment has been named the National Scorecard Initiative, and has been endorsed, and is expected to be accredited, under the Nationwide House Energy Rating Scheme (NatHERS) (State Government of Victoria, 2022).

Housing energy assessments have been developed by a range of organisations; national, state, and local governments; collaborations between governments such as regional authorities; utility companies; not-for-profit organisations; for-profit community organisations; and private companies. A list of rating tools globally is included in Appendix 1 – Housing energy assessments worldwide.

2.2 Criteria to analyse effectiveness, efficacy, and trust of assessment tools

It is important to first clarify the desired outcome of a home energy rating, and then consider the best practice learnings on how to ensure the rating delivers this outcome.

To be effective, programs must first clarify what they aim to achieve and then propose an approach that will produce the intended result. There is broad support for housing assessment, and many evaluations of these programs have been undertaken, generating significant learnings (Brown et al., 2021; Cespedes-Lopez et al., 2020; Jenkins, Simpson, & Peacock, 2017; Kelly, Crawford-Brown, & Pollitt, 2012; Kurmayer, 2021; Marmolejo-Duarte et al., 2020; Sunderland & Santini, 2021).

This section reviews the literature and develops a set of criteria for a best practice housing assessment that supports understanding of the current energy and carbon performance of a dwelling, to allow comparison between dwellings, to drive home upgrades, and to monitor energy performance of the Australian building stock.

2.2.1 Objective of a housing assessment

The literature review found that there are generally two main desired objectives of a housing assessment. One objective is supporting public policies such as minimum building standards; public disclosure of assessments for buyers, renters, and policy makers; or broad scale housing stock assessment. This requires a consistent, standardised, objective, trustworthy, transparent, validated approach. This is critical because there is otherwise an incentive to deliver assessments that overstate performance, or risk collecting poor quality data that is not trusted or useful.

Another objective is to support households who do not want to share their assessment results and who wish to consider subjective personal data such as their individual behaviours, different retail energy costs, and different ways they could operate the home. As the assessment is not to be shared there is little incentive to overstate performance. In this case, subjective information is needed to generate a rating and privacy protection is more significant. It is still important that the rating is consistent, standard, trusted, transparent, and valid. These assessments that reflect the current household energy use, rather than an average user's energy use, may support householders private actions but have been found to be ineffective in driving upgrades during real estate transactions and erode trust in the certificate (Jalas & Rinkinen, 2022). They also fall outside the scope of this report.

2.2.2 Housing assessments should be accurate and trusted

It is widely agreed that a core requirement of housing assessments is that stakeholders must trust the rating and the advice on best value upgrades for their home (Al-Addous & Albatayneh, 2020; Collins & Curtis, 2018; Hill et al., 2016; Kurmayer, 2021; Taranu & Verbeeck, 2018; Taranu et al., 2020).

The main methods to generate trust in the program and accuracy of the assessment based on the literature review follow.

- Assessments cover the main fixed energy using assets of the specific home being assessed to ensure the rating is useful, accurate, and trusted. In-home assessment is essential to avoid assumptions based on broader built form due to the high proportion of renovations, deterioration over time, and the wide variety of performance.
- Skilled and trained assessors that visit the home to collect data that is entered into a standardised tool to generate assessments and upgrade options. Self-assessment or semi-skilled assessors do not meet the objectives in the scope of this report.
- Program quality controls including auditing of assessments and penalties for substandard assessments
- Standardised, objective data collection, and the avoidance of subjective data (such as specific householder behaviour or unfixed appliances), which can be used to manipulate results. Support material and programs such as standardised procedure manuals are required.
- Program opt-out options should be avoided as this may lead to failure of the program.
- Assessment methodologies and assessments should be transparent, piloted, and tested in a wide variety of real homes and climates to ensure assessments fairly represent actual home performance.
- Programs should be regularly evaluated, and new technologies included.

It is important housing assessments are accurate, for example three homes that look generally similar may actually achieve very different outcomes when on-ground conditions such as draught proofing, insulation, deterioration, and age of appliances is examined. Hence, on-ground assessment is the method used internationally to deliver assessments. Internationally, various approaches have been used over time to reduce cost by using self-assessment, third party data, or assumptions relating to broad house characteristics. Evaluation has not been positive suggesting these assessments are not considered to be accurate or trustworthy. Best practice evaluations consistently suggest skilled assessors are needed to collect information in the home and generate assessments. These assessors must pass training and examination to demonstrate the skills needed.

Opportunities to manipulate results to achieve higher ratings are likely to lead to inaccurate results. Therefore, tools should be supported by standardisation, objective data, default settings, accredited assessors, and audits. Mandatory programs generally do not provide opportunities to opt out of assessments, as this undermines the core requirement of comparability and risks undermining the overall goals of informing stock condition and retrofit options. Successful programs have transparent methodologies that have been repeatedly tested in real homes in a wide variety of climate conditions. Programs are then evaluated regularly to ensure they continue to deliver the policy objectives.

Subsidiary issues have also been investigated in the literature. A key issue is whether assessments should attempt to predict actual energy costs of the specific behaviours of a given household. Actual energy bills are driven by variable occupancy, specific activities undertaken on site, and specific and changing energy tariffs as examples. Many of these variables are not connected to the energy efficiency of housing *per se* and hence the following discussion is largely contextual rather than specifically in scope of housing assessment for disclosure purposes. Given that this outcome does not support the overall policy objective it is important to not raise expectations that a housing assessment can be both objective, comparable and repeatable, and also be used to predict specific energy bills of a given household at a point in time. Indeed, attempting to model these variables is inconsistent with the objectives of objectivity, comparability, repeatability, and representing the overall performance of building stock over time.

Advocates of including additional real occupant data, in particular smart meter data, argue that they could offer an easy, low cost way to deliver improved quality and information about the use of the dwelling. This could perhaps support alternative policy objectives than those addressed here (see above). An ongoing large-scale data collection and analysis project from the UK, the Smart Energy Research Lab (SERL) Observatory, has been collecting smart meter data (electricity and gas), EPC information, and local weather data for more than 13,000 dwellings since 2019 (SERL, 2022). This project has provided insights into whether and how an EPC-type approach could be achieved through data mining of larger data sets and the use of smart meter data. The research has identified some challenges in this approach. For example, despite the belief that smart meter electricity data should be fairly straightforward to collect, 11.5 per cent of data was missing. Furthermore, smart meter data for gas and water is not widely undertaken limiting the use of this data to electricity. This has implications in relation to those who want to include more data points within assessments.

The extent to which real energy data can be utilised and the value of this data is debated (Al-Addous & Albatayneh, 2020). For example, the data itself does not say how the house is used, or if the occupants are 'typical' or not in their energy consumption, and so may have limited benefit for others. Researchers have also noted the impact that household practices have on assessments (Brown et al., 2021).

Building Information Modelling (the digitisation of building design, performance and management in a single tool) and Blockchain (a digital secure database to track information and transactions) are among the digital innovations which have been proposed as potentially speeding up the assessment and accuracy of assessments (Li et al., 2019). However, it is also noted that a key challenge for the introduction of any new modelling software or data set is to ensure consistency of the specific software and also the input of data by users. Tools like Building Information Modelling and Blockchain are not currently widely used and leave open the questions of independent verification. Notwithstanding, they could save assessment time in future assessments (e.g., through not having to create a new model each time the dwelling is assessed).

The role of modelling data is contested, with many researchers cautioning against over-reliance on thermal modelling software due to issues with assumptions of occupant practices and other trade-offs required (Al-Addous & Albatayneh, 2020; Daniel, Soebarto, & Williamson, 2013; Egan et al., 2018; Kordjamshidi, 2013; Miller et al., 2021; O'Leary et al., 2016). Furthermore, such improved modelling software is often resource intensive (Egan et al., 2018).

A summary of methods that have been proposed to reduce the gap between modelled data and actual performance data includes:

- a calibration process whereby theoretical data is revised against actual data until results are within five per cent of each other,
- using more data points and the most influential data points,
- using improved building modelling software which would create a digital model of the dwelling and undertake energy analysis based upon design and construction, and
- other innovations such as Blockchain (a digital secure database to track information and transactions).

A number of key house energy rating approaches have reported on the need for continual analysis and review of assessment methods to ensure improvements where needed. For example, the US Department of Energy Home Energy Score program analysed their first year of data (~7,000 dwelling assessments) and based upon these findings undertook more detailed analysis including developing simulations for another 1,000 homes to help revise the assessment process and validate data outcomes (Glickman et al., 2014). This evaluation and revision led to several changes within the program including the use of more weather location points (from ~250 to more than 1,000) to improve data accuracy. The changes to assessment methods had a significant impact on the scores of dwellings (see Figure 3).

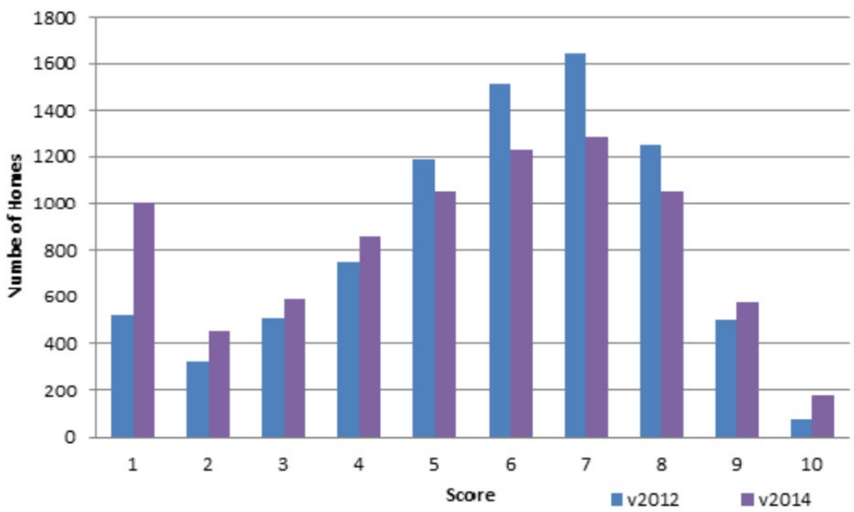

Figure 3. Starting Score of homes using the Home Energy Score program v2012 compared to changes introduced in v2014 (Glickman et al., 2014, p 163).

The assessment methods are usually supported by procedures, guidelines, a code of ethics, manuals, and databases to support uniform assessments. For example, EnerGuide developed (Parekh et al., 2000):

- Administrative Procedures
- Technical Guidelines
- Evaluation Procedures
- Quality Assurance Procedures
- The Certification Process and Energy Efficiency Rating Label
- Code of Ethics
- Evaluator Workshop Manual
- EnerGuide for Houses Database.

2.2.3 Assessments should be consistent

It is important to have a low variability of assessments so that different assessors generate a consistent assessment for a given dwelling.

This also supports trust in the program and accuracy of the assessments. Based on the literature review important features are:

- Training, mentoring, auditing, and penalties for assessors - consistently raised as an important program requirement.
- Standard default assumptions should be set where information is not available or not needed to be collected.
- Such default assumptions should be a reasonable worst case, or the minimum standards in place at the time of building, rather than those in place now.
- Subjective data should not be collected and where possible evidence such as photos collected to support the validity of the data collected.

The consistency of assessments has also been noted as an important priority, including when it relates to appliances and other technologies. Limited available on-ground information, or availability of subjective selections in rating tools can result in significant implications for consistency and accuracy of assessments.

Numerous researchers raised issues with having different assessment approaches across jurisdictions because this limited the ability to compare outcomes and share learnings and ultimately improve assessment tools and outcomes (Semple & Jenkins, 2020). The variance in approaches and methods was also noted across the EU where there is common directives and goals in relation to improving sustainability outcomes for the built environment (Jenkins et al., 2017; Semple & Jenkins, 2020; Sunderland & Santini, 2021, p. 3). Zirngibl and Bendžalová (2015) reported there were at least 35 different methods across EU countries for how to calculate EPCs.

2.2.4 The role of trained assessors

Training is a basic requirement for home assessors to address the basic criteria of trust, accuracy, replicability, and householder support. Generally, in the programs examined, specific tool and assessment training is offered, sometimes free, and sometimes incentivised with funding. Funding has been recommended in programs that are voluntary and hence lack an incentive to participate. Funding can be targeted particularly to ensure unrepresented communities become assessors.

In many jurisdictions where a house energy rating is mandated (e.g. at point of sale or lease) there is typically a requirement that the person doing the assessment is an accredited assessor who demonstrates minimum levels of knowledge and competency (Andaloro et al., 2010). Most analysis suggests the training needs to be continually improved over time.

Government funded voluntary programs that incentivise upgrades also typically require an accredited assessor to develop a trusted and consistent assessment, e.g., the US Home Energy Score assessment. The US Department of Energy requires all Home Energy Score assessments to be undertaken by a certified Building Performance Institute Building Analysts or Residential Energy Services Network (RESNET) Raters (Glickman et al., 2014). Even with that requirement, the pilot phase of the Home Energy Score revealed additional training was required to up-skill assessors for the specific use of the new tool. Additional free online training was developed, and assessors needed to complete the training to deliver assessments.

In Australia, training is required to deliver Scorecard assessments. Training covers the skills required to identify house features accurately, health and safety, use the tool, and provide appropriate advice to householders (DELWP 2019). Scorecard training is designed to cover the skills needed in the field and is constantly updated with consideration of assessor and trainee feedback and the results of audits of assessments.

The experience from the USA reveals that there may be a need to train and accredit more assessors to ensure demand for assessments can be met when programs are scaled-up. In particular Glickman et al. (2014) reflect that if a tool like Home Energy Score is to scale-up and be used during housing transaction processes that there will be a need for improved online training options.

Sufficient training, mentoring, and auditing of assessors is consistently raised as an important program requirement. Monitoring variance between different assessors evaluating the same dwelling is a critical quality control measure (Glickman, 2014; Hårsman et al., 2016; Hill et al., 2016; Kurmayer, 2021; Las-Heras-Casas et al., 2018; Organ, 2021). One study analysed assessments by 145 assessors of 29 sample dwellings (with each having at least four assessments plus a control assessment) and found that in about two-thirds of assessments the assessment rating varied by at least two energy performance bands (Jenkins et al., 2017). The areas in the assessment where there was least consensus amongst assessors was roof efficiency, total floor area, light efficiency, and glazing efficiency.

In addition to the focus on assessor training, there is an increasing use of auditing of assessments and assessors to improve quality and consistency of assessments as well as to inform improvements to tools and training approaches. For example, some programs in North America require accredited assessors to undergo a random sampling of rating reports either through a simple desktop audit or a more detailed site visit (Hill et al., 2016).

A UK study found that almost one-third of homes could have been placed in the wrong EPC energy rating band (i.e. A to G) (Hardy & Glew, 2019). Other work attempts to quantify a measurement error in EPCs by reviewing a sample of 1.6 million dwellings that had exactly two EPCs in England/Wales (Crawley et al., 2019). In total 52 per cent of dwellings were found to change energy band between the two EPCs. Whilst many of these homes would have achieved this through a genuine improvement in energy performance (through active energy efficiency programs between the two EPC assessments), 19 per cent of the 1.6 million showed a lower (i.e., worse) energy rating in the second assessment. One study suggested that only 60 to 80 per cent of EPCs are good quality (Li et al., 2019).

Another study found that 15 per cent of multi-family homes in Sweden had multiple EPCs that were not comparable due to significant disagreements between assessors (e.g. significantly different heated floor area recorded) (von Platten et al., 2019). In a study from Italy a dwelling was evaluated by 162 independent assessors with 70 per cent determining the right rating outcome (Tronchin & Fabbri, 2012). The 30 per cent inaccurate responses were attributed to poor computer and program use, and a lack of understanding of the input data. In Spain up to half of EPCs have been found to have issues with data quality (Las-Heras-Casas et al., 2018).

Consistency between assessors and across housing types and climate zones was noted as an early critique of the US Home Energy Score program (Glickman, 2014). A recommendation was to improve training and include more detailed modules of learning for assessors and to add an R-value calculator to help the Home Energy Score achieve its aim to provide accurate and consistent information. Training is promoted as being offered by local and national partner organisations and integrated into the system: 'The Home Energy Score has a fully functional, web-based user interface and web application programming interface (API), integrated training tools to customize dashboards for multiple user types (e.g., administrator, assessor, mentor, etc.), and enhanced data security systems' (US Department of Energy, 2022). BPIE (2010) state that the majority of assessment errors are due to human error from the assessor.

The wider research suggests training, professional development, mentoring, auditing, and penalties as options to address these issues.

In all existing homes an important issue is that some elements will not be accessible, or alternatively it will not be cost-effective to collect all possible data. Assumptions based on the building regulations in place at the time can be used, with an alternative default to the lowest likely performance if no standards were in place. This will ensure that the data cannot be manipulated to improve a home energy rating, and avoid the uncertainty generated by use of subjective assumptions. An assessor is required to provide objective data of higher performance (such as a photo of ceiling insulation) before it can be claimed. It is important that evidence for key data points is collected and stored as part of the rating, to help prevent subjective data being included in assessments.

It is important that this approach is used. In the UK where this was not considered Ahern and Norton (2020) identified that a standardised thermal bridging transmittance coefficient (Y-value) is often used in combination with worst-case overall heat loss coefficients (U-values) to avoid incorrectly greater EPC ratings for all existing dwellings. The default U-values for roofs, walls, and floors are based on the building codes and regulations in effect at the time of construction. Many older houses have had considerable structural improvements. As a result, the default U-values are far higher than the actual U-values of those updated homes. In large national EPC datasets, this results in a systematic 'default effect' error. Thermal default use overestimates potential primary energy savings from upgrading by 22 per cent and 70 per cent in houses built before and after thermal building rules, respectively, for the dataset examined.

In summary, inconsistent, and incorrect assessments should be avoided by careful program design.

2.2.5 Assessments should be accessible and householder-focused

It is important that the assessments are communicated in a way that people can understand and that best helps them upgrade their home.

Based on the literature review important features are:

- There needs to be a public awareness raising campaign to support trust and understanding of the program and its benefits.
- Assessments must be provided at point of advertising. Requiring householders to request assessments is not effective.
- Assessments need to move beyond generic information and provide specific comparable assessments and upgrade suggestions for the particular home being assessed. Assessments should be credible (skilled assessors) and persuasive (robust transparent tool).
- Housing assessment scales should ensure that most house forms have a plausible path to improve assessments, this ensures engagement with the process of improving assessments.
- Assessment scales should be simple and intuitive for the average householder, not technical or requiring explanation to understand relative performance. Consumer testing should be used to ensure assessments are designed to meet these needs.
- Assessments need to cover cost, energy, and carbon and include rating related to comfort (liveability, health and wellbeing).
- Communities need to be supported with information in their language and programs should ensure home assessors are available that are multilingual and understand the needs of specific communities.

A lack of householder relevant information has also been identified as limiting the benefit of some house energy rating assessments (Comerford, Lange, & Moro, 2018; Glickman, 2014; Glickman et al., 2014; Marmolejo-Duarte & Ampudia-Farias, 2018; Organ, 2021; Oskouei, et al., 2020; Taranu & Verbeeck, 2018; Zuhaib et al., 2022). Assessments need to move beyond generic information and provide specific recommendations for the particular dwelling being assessed.

It is not just the specific information that is identified, but the broader information as well. Encinas et al., (2020) note issues with the different approaches to communicating outcomes and reflects that the use of standard letter bands (e.g., A to G) becomes harder for consumers to understand when nuances such as '+' signs are added to indicate additional improvements. This information also needs to move beyond just cost, energy, or carbon metrics and provide information on impacts to liveability, and health and wellbeing, which can be more relatable outcomes for households (Glickman et al., 2014).

Furthermore, information must be presented in a household's preferred language to improve understanding. Multi-lingual assessors is important in this regard and can help build trust between the assessor and household (Hewitt & Boucher, 2021).

In their investigation on how technical information is translated for residents, Taranu and Verbeeck (2018) highlighted that the EPC is widely recognised as an important policy tool for improving energy efficiency in the residential sector. However, the certifications of nine European countries/regions revealed a wide range of information framings and possible prompts that were examined using the 'lenses' of behavioural insights. They highlighted the units for the energy performance indicator, as well as the recommendations, as key considerations. Their analysis revealed a wide range of units that denoted energy consumption, energy efficiency, CO_2 emissions, monetary savings, and even unitless.

In the UK and the US an early learning was that the rating scale did not provide a path to improve assessments for certain home typologies (Glickman et al 2014). This leads to disengagement. It is important to ensure a plausible path to improving a housing assessment by careful analysis of the implications of a scaling approach.

Marmolejo-Duarte and Ampudia-Farias (2018) present similar outcomes, using choice experiments to compare residential attributes of apartments in Barcelona (such as condominium amenities, private space arrangements, quality of finishes, and active thermal conditioners). The consequences of energy efficiency in economic and environmental terms were informed using technical and illustrative units to investigate if an information framework could influence household decisions. The findings indicate that respondents value energy efficiency highly. This preference is stronger when households are informed using simple illustrative units rather than the technical ones found in the text. Because most residential consumers are not experts in this sector, this latter finding has significant implications for energy policy and implies that more attention should be addressed to the design of energy efficiency communication. Policy efficacy is enhanced by simple, clear messaging of information in EPCs.

Comerford et al. (2018) proposed that the important colour-letter grades on the English EPC acted as targets for vendors, driving them to invest in energy efficiency. They used a random sample of over 16,000 residences in England to test the hypothesis and came to the conclusion that a well-designed energy labelling policy may encourage upgrading and greening the housing stock.

It is important that the program is supported by appropriate communications, communicating to householders why the program is beneficial and how they can benefit. The reputability of the delivery body is also critical. Some studies have found that housing consumers have a lack of trust in the governing bodies who develop and operate house energy rating assessment programs and that this lack of trust in the governance impacts negatively on the perception of the assessment (Schuitema, Aravena, & Denny, 2020). It was found that it is important for regulators and assessors to improve their own credibility if the credibility of the assessment it to improve.

Broader communication of broader benefits is also important to gain the social licence to store data. Privacy protection is an important consideration for householders. This is particularly important in creating a repository of housing stock information for general access. For example, one study of more than 2,500 households across the EU identified a third of respondents were concerned with the security of dwelling information (including any 'smart' data) collected as part of any house assessment (Zuhaib et al., 2022). The same study found mixed support for how public performance data should be made, with around 40 per cent of respondents stating they wanted their dwelling information to not be made public, or if it was, that it was anonymous. However, governments collect and share substantial datasets that generate public policy benefits, indicating that communities need to understand the benefits of data collection and program delivery needs to consider how concerns can be addressed.

Australian analysis (Allen Consulting Group, 2011) posited that consumer focused home energy assessments were important to drive upgrades in a mandatory program, finding factors that would increase the likelihood that householders would use assessments to upgrade their home:

- Benefit of having an assessor-based rating (credibility)
- Benefit of having a rating for comparative purposes (generates incentivisation)
- Benefit of improved rating model for use by assessors (persuasiveness)
- Benefit of robust detailed thermal assessment (quality).

2.3 Analysis of selected assessment tools

As Section 2.1 Overview of housing assessments worldwide demonstrates, there is growing experience in housing energy assessments, notwithstanding that they vary in their design, objectives, scope, approach, method, and outputs. While there are common objectives in relation to developing outputs that provide information and influence behaviour, there are also distinct objectives in relation to outcomes for housing such as the focus on health by the Department of Natural Resources Canada. The approach to implementation varies nationally including integrating EPCs in policy instruments such as building codes in the EU, voluntary programs aimed at the household level, and, in addition, energy retailers, private companies and community-based organisations have developed tools for their specific audiences.

How assessments are undertaken, their scope, method, and outputs, and the various criteria that determine effectiveness and efficacy, are all factors to consider in any analysis of housing assessments. These core design elements are shown in Figure 4.

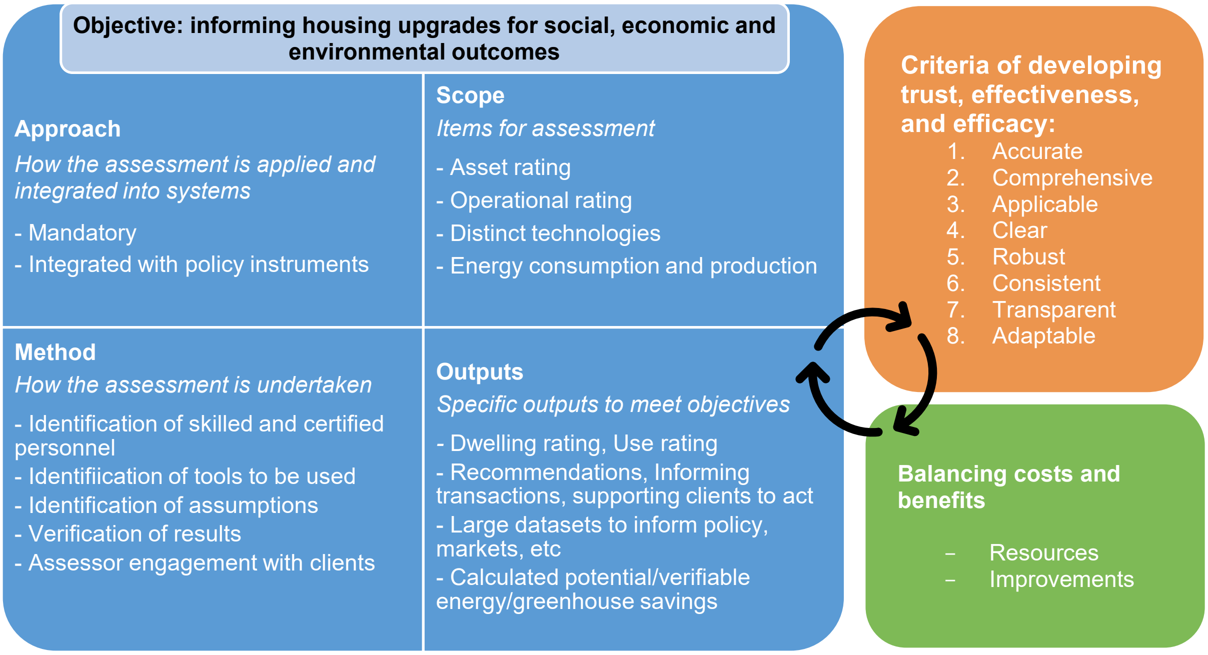

Figure 4. Assessment design elements

It is important to take a deeper look at these design elements to inform analysis about tool requirements. Consequently, the following section describes seven selected tools that include a range of designs, well-established programs and innovative approaches, and information about their cost-effectiveness, in order to provide a detailed understanding.

The assessment tools are:

- Europe – Energy Performance Certificates.
- UK – Energy Performance Certificates.
- US – Home Energy Score.
- Canada – EnerGuide.
- US – New York State Energy Research and Development Authority.
- Australia – Scorecard.
- Australia – Mandatory disclosure ACT.

Details about the assessments are included in Table 1 for easy comparison. Analysis through the literature follows.

Table 1. Key housing energy assessments.

Tool	Lead	Lead Sector	Jurisdiction	Year introduced	Program evaluation	Design
Energy Performance Certificate	European Union	GOV	Europe	Required through EPBD since 2002	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** Support a mandatory program. An information tool for building owners, occupiers and real estate actors, to contribute to the enhancement of the energy performance of buildings. A market tool to create demand for energy efficiency in buildings and to influence consumer choices. • **Approach:** Mandatory requirement for rating for new constructions and buildings with major renovations, and to be given to a new tenant or buyer for buildings that are constructed, sold or rented. There are also requirements for public authorities. • **Scope:** Best practice considered to be On-ground assessment of the home • **Method:** Mostly accredited assessor and tool. Quality control: Independent control inspections of EPCs. • **Output:** Rating certificate. EPCs include the energy performance of a building and its reference values such as the minimum energy performance requirements and recommendations for cost-optimal or cost-effective improvements. The EPC covers the measures associated with a major renovation of the building envelope or technical building system and individual building elements. • **Source:** https://ec.europa.eu/energy/eu-buildings-factsheets_en
Energy Performance Certificate	United Kingdom government	GOV	United Kingdom	2007	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** Support a mandatory program. To provide accurate and reliable assessments and comparisons of dwelling energy performances to underpin energy and environmental policy initiatives. • **Approach:** Mandatory whenever a property is built, sold or rented, before it is marketed. Fines may be given if an EPC is not obtained when required. The Standard Assessment Procedure (the methodology to assess and compare the energy and environmental performance of buildings) is included in the Building Code. • **Scope:** On-ground assessment of the home. Energy use per unit of floor area, a fuel-cost-based energy efficiency rating, and emissions of CO_2. Based on estimates of annual energy consumption for the provision of space heating, domestic hot water, lighting and ventilation. Other SAP outputs include estimate of appliance energy use, the potential for overheating in summer and the resultant cooling load. • **Method:** Accredited assessor and tool. SAP assesses energy consumption when delivering a defined level of comfort and service provision. Includes standardised assumptions for occupancy and behaviour.

Tool	Lead	Lead Sector	Jurisdiction	Year introduced	Program evaluation	Design
						• **Output:** Rating certificate. The EPC provides information about a property's energy use and typical energy costs, and recommendations about how to reduce energy use and save money. An EPC gives a property an energy efficiency rating from A (most efficient) to G (least efficient) and is valid for 10 years. • **Source:** https://www.gov.uk/buy-sell-your-home/energy-performance-certificates, https://www.gov.uk/guidance/standard-assessment-procedure
Home Energy Score	US Department of Energy (DOE) – Washington, D.C	GOV	North America	2012	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** National standard assessments approach to mandatory and financial incentive programs. To provide homeowners, buyers, and renters directly comparable and credible information about a home's energy use to motivate upgrades to improve home energy performance and promote communication about energy performance in real estate transactions to influence decision-making. • **Approach:** Voluntary standardised national approach, mandatory in some jurisdictions, incentivised in some jurisdictions. Several cities have required Home Energy Scores when homes are listed for sale to increase transparency into home energy use and expected costs for buyers and renters. • **Scope:** Generally on-ground assessment of the home to easily compare energy use across the housing market. Assessment based on attributes, envelope and equipment; and assumed occupant profiles. • **Method:** Accredited assessor and tool. DOE-trained Home Energy Score Assessors. Web-based tool with enhanced data security systems. Local and national Partner organisations providing training, mentorship, and quality assurance requirements. • **Output:** Ratings certificate. Home Energy Score on a simple one-to-ten scale. Ten is the most efficient homes. Estimates home energy use and associated costs, and makes recommendations for cost-effective improvements, includes a "Score with Improvements" that reflects the expected score and savings if the recommendations are implemented. • **Source:** https://www.energy.gov/eere/buildings/articles/home-energy-score, https://www.energy.gov/eere/buildings/articles/does-home-energy-scoretm-recognized-technology-transfer-achievements
EnerGuide	Department of Natural Resources Canada	GOV	Canada	1998	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** Support a financial incentives program, Promote energy efficiency retrofits in existing housing. • **Approach:** Voluntary program supported by financial incentives for assessments, upgrades and assessor accreditation.

Tool	Lead	Lead Sector	Jurisdiction	Year introduced	Program evaluation	Design
						• **Scope:** On-ground assessment of the home for comparison with other homes in the region. Assessment based on attributes, envelope and equipment. • **Method:** Accredited assessor, and tool. NRCan's energy simulation software uses standard operating conditions. Specific household operating conditions are used to provide recommendations. Energy Advisor registered with Natural Resources Canada. • **Output:** Ratings certificate. EGH evaluator estimates the home's annual energy requirements. EGH evaluator produces a label that includes an estimate of the annual energy requirements of a house, provides a comparative rating, and provides a report including recommendations to improve energy efficiency, and to improve indoor air quality and comfort. • **Source:** https://www.nrcan.gc.ca/energy-efficiency/energuide/energuide-energy-efficiency-home-evaluations/20552
Home Energy Efficiency Programs	New York State	GOV	New York State		Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** Support a financial incentives program. Encourage investment in home energy efficiency. • **Approach:** Voluntary programs supported by financial incentives for assessment and upgrades to identify energy consumption and provide assistance in implementing energy efficiency improvements. Renters need approval from landlords to engage in the programs. Various sub programs include Residential Energy Audit, loan options for financing for eligible applicants including Residential Financing and Assisted Home Performance with ENERGY STAR. EmPower New York targets low-income residents. • **Scope:** On-ground assessment of the home. Home energy features and household consumption. • **Method:** Accredited assessor, and tool. After the assessment, the results are reviewed with the auditor. • **Output:** A report including energy performance and a prioritised list of recommended improvements. • **Source:** https://www.nyserda.ny.gov/All-Programs/home-energy-efficiency-upgrades, https://www.nyserda.ny.gov/All-Programs/Energy-Audit-Programs
ACT House Energy Rating Scheme (ACTHERS)	ACT Government	GOV	ACT	1999	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** Support a mandatory program, provide independent information at point of sale or lease to influence consumer decision-making. • **Approach:** Mandatory disclosure of a rating (EER) home in advertising at the point of sale or lease. The Rating Certificate must be provided at the point of sale.

Tool	Lead	Lead Sector	Jurisdiction	Year introduced	Program evaluation	Design
						• **Scope:** On-ground assessment of the home in addition to an assessment of house plans held by government rating of thermal efficiency. • **Method:** Accredited assessor, and tool. • **Output:** Rating Certificate. • **Source:** https://www.frontiersin.org/articles/10.3389/frsc.2022.801460/full
Victorian Residential Efficiency Scorecard/ National Scorecard	Victorian Government	GOV	Australia	2017	Yes multiple, program generally found to be beneficial with many learnings	• **Objective:** National standard assessments approach to support mandatory and financial incentive programs. Provide support for households to reduce energy costs, carbon emissions and comfort, including keeping the home cooler in summer and warmer in winter to protect people's health and wellbeing. • **Approach:** Voluntary programs, supported by financial incentives for assessment and upgrades in some locations, used to support lower cost loans by some financial institutions. • **Scope:** On-ground assessment of the home. Includes hot and cold weather ratings to assess comfort in extreme weather. • **Method:** Accredited assessor, and tool. Quality controlled, including through photos taken by the assessor. • **Output:** Rating certificate Suggestion of upgrades to reduce energy cost, and to protect health and well being. • **Source:** https://www.yourhome.gov.au/buy-build-renovate/building-rating-tools, https://www.homescorecard.gov.au/

2.3.1 Scope of selected assessment tools

Existing energy assessment tools generally have similar characteristics. They cover the built form and fixed appliances and use a ‘standard’ occupant profile to ensure that assessments are standardised and comparable and to avoid deliberate or accidental manipulation of results.

Common elements used to inform a house energy rating include:

- Climate zone
- Year of construction/major renovations
- Orientation and performance of windows
- Floor area and conditioned floor area
- Performance of key construction materials (walls, floors, ceiling, windows, insulation), draughts and gaps
- Efficiency of fixed appliances (lighting, hot water, heating, cooling, pools)
- On site renewable energy.

These elements can also vary in the data gathered and associated methods, providing either a more limited, or holistic picture. For example, a comprehensive asset rating is undertaken through the EnerGuide Rating System (Canada) (Government of Canada, 2022b). A more extensive assessment also includes level of the home’s airtightness, using a blower door test and active ventilation.

In Europe, Germany provides two sorts of energy performance certificates: consumption certificates and requirements certificates. The certificate of consumption is based on recent energy consumption, which is heavily influenced by the tenants' habits. The requirements certificate assesses a building's energy requirements, regardless of occupant behaviours, and is reviewed on-site by an accredited energy consultant who details the building's structure and heating system.

2.3.2 Outputs

As noted earlier, a key driver of housing assessments is to improve the quality, consistency, and clarity of information on home energy performance and upgrades. This overcomes the information barrier as householders do not know their current home energy performance, how to improve this performance, and who to trust to gain this information. Households can then make more informed decisions about upgrades to their homes, or decisions about homes that they may buy or rent. Trusted information also supports retrofit businesses to develop, avoiding the ‘market for lemons’ issue that hampers industry development (Fuerst & Warren-Myers, 2018; Hurlimann et al., 2018). The availability of information on home energy performance also supports the development and implementation of policy and support programs. Therefore, presenting information in a way that is accessible and trustworthy is important for household comprehension and influencing action (Andaloro et al., 2010).

2.4 Balancing costs, benefits and outcomes

Key to optimising housing assessment tools is the balance between the cost of the assessment and the usefulness of the outputs. For example, there are diminishing returns if accuracy is over prioritised, which increases the cost to secure and verify data. Alternatively, if low cost is prioritised, this might compromise the outputs such that they are not useful and do not deliver upgrades. Figure 5 shows this trade-off between accuracy and expense based on the US experience (US Department of Energy, 2021). In the case of the Home Energy Score program identified in the figure, the program requires an accredited assessor to visit homes and use of EnergyPlus software (for heating and cooling, infiltration and other performance modelling) to complete the assessment.

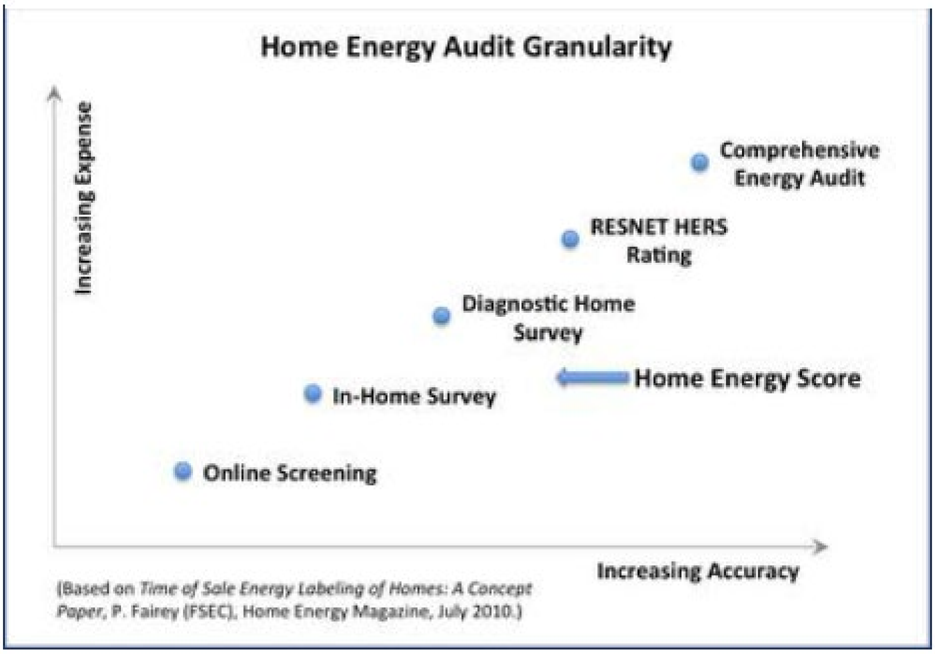

Figure 5. Accuracy and expense of home energy audit tools US (US Department of Energy, 2021a)

The following sections summarise evidence across the literature on how trade-offs have been approached and how benefits and outcomes are understood and pursued.

2.4.1 Home assessment cost

Key findings

Housing assessment must drive upgrades to meet the objectives defined in this report.

- The outcome (impact) from housing assessments is fundamental to meeting objectives and has a higher value that the cost of the rating.
- The home assessor needs to be physically present onsite to gather the technical information required and generate specific recommendations for upgrades.
- Home assessment costs fall under mandatory programs, due to the volume of assessments thereby driving efficiencies.
- Voluntary programs require investment in marketing and subsidies for assessments.

Trained and accredited assessors that visit the home

Home energy assessments used internationally at scale are generally similar, mostly requiring a trained and accredited home assessor and a standardised assessment tool and methodology. This provides on-ground home assessment of actual home features, through a reputable source (skilled assessor) and the ability to engage directly with the householder. The cost to visit the home sets the base cost of the assessment. Some countries also mandate more extensive assessments such as blower door testing for draughts which increases the time spent on the assessment and hence cost.

If skilled assessors are not required to visit the home this reduces costs, however evaluations suggest that this is not best practice. Assessments that do not require a skilled assessor to visit the home have not been found to generate home upgrades, both in EU and Australian evaluations (see above). In the EU, the home assessor needs to be physically present onsite (for existing buildings) to gather the technical information required for the certification process. On-site inspection may influence better quality and reliability of the EPCs and allows for more effective tailor-made recommendations (BPIE, 2010).

In terms of time to undertake the Home Energy Score assessment it was found that 'The pilots confirmed that Qualified Assessors can collect and enter required data and score a home in an hour or less. If the assessor is already doing some type of home energy audit or assessment, the scoring will typically require only an additional 15 minutes of effort' (Glickman, 2014, p. 10). It was noted this time should drop further as the integration of application programming interface for the tool was made available with other pieces of software.

EU analysis considers the value of housing assessments should be linked to their usefulness, reliability, public acceptance, and therefore their impact on market decisions that drive improved home performance. This outcome from housing assessments is considered as having a higher value than the cost of obtaining the rating. Higher value is attributed when assessments bring benefits, such as cost-saving renovations with short payback periods, or an increase in the selling value of a property.

Housing assessments, especially across the EU with EPCs, generally require the use of an accredited assessor. It has also been found that a negative perception of value can occur if assessment tools are seen to be 'low-cost', negating benefits (BPIE, 2010). The following is a list of assessment costs in 2010 for different European jurisdictions, although it is not clear if this is the cost to the household or inclusive of any rebates or financial incentives which were available at the time.

The list demonstrates a wide variance in costs for certification ranging from €45 to €800 (BPIE, 2010):

- Germany: between €45 and €500.
- France: between €50 and €300.
- Austria: for multifamily houses about €150-180 per home, for single family.
- houses about €450.
- Belgium: for an apartment starting from €205, for a dwelling starting from €245.
- Czech Republic: about €500-800.
- Denmark: about €700-800.
- Poland: about € 50-100.
- Portugal: about €224-324.
- The Netherlands: about €200.
- Ireland: about €200.
- Spain: about €800.
- Hungary: about €50.

Research from 2014 shows that the cost of EPCs has fallen with 85 per cent less than €300 and 63 per cent less than €200 (Figure 6). More recent research seems to suggest that the prices for EPCs have stabilised with the cost for a residential house between €100 to €300 (Li et al., 2019). This indicates that as assessments scale-up there should be efficiencies for cost of delivery.

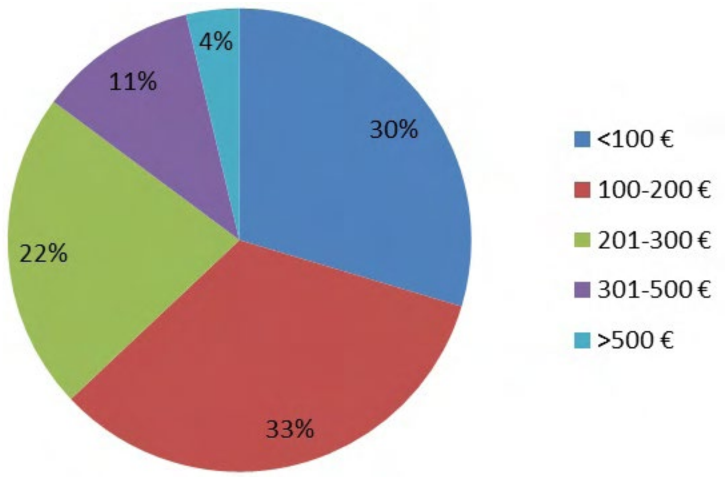

Figure 6. Cost of EPCs for single family homes, based on national reports 2014 (EPBD, 2016).

The report states that 'the lower cost certificates (frequently based on measured rating) are often of lower quality. This is often a politically motivated choice linked to public acceptability. A low-quality EPC, however, is often less valued by the public while a better-quality EPC provides the building owner with more useful information. It is important to find a balance between the price and the information value that the certificate offers' (BPIE, 2010, p. 35).

In the US, where home assessments are generally voluntary and may be subsidised, there are different drivers at work, than where assessments are mandatory as in the EU. Interviewees indicated that in order for voluntary assessments to be attractive the cost to homeowners needed to be in the vicinity of US$100 to US$200 (Bonnitcha & Davies, 2016). In some US states like New York, the cost for assessments is subsidised so the amount that the household pays is determined by household income level, helping to reduce costs for some homeowners (Hewitt & Boucher, 2021). The New York State Energy Research and Development Authority (NYSERDA), also incentivises retrofit programs and incentives, including rebates for certain equipment installations and loans for energy efficient home upgrades (Hewitt & Boucher, 2021). They often bundle these assistance programs with a free house energy rating. The same organisation providing both the assessments and support programs for retrofit was seen to improve information flow and streamline the process, helping households make easier retrofit decisions and opening up retrofit access to more people (Hewitt & Boucher, 2021).

In Victoria, the cost of undertaking a Scorecard assessment has been estimated to be between AU$250 to AU$500 (DELWP, 2022a). This cost was noted to consider a range of factors including travel time for assessors, dwelling size and complexity, and the needs of the household. Feedback from the industry found that Scorecard assessments would cost approximately AU$320 to AU$350 as standalone assessments, and AU$250 when bundled with other services but that costs associated with lead generation under a voluntary program was estimated to be an additional AU$50 to AU$100 per assessment (Point Advisory, 2018).

There is a significant difference in assessment costs depending on whether the program is voluntary or mandatory. As in the EU, mandating drives down assessment costs due to the large volume of assessments undertaken, the ability for assessors to develop businesses providing assessments, and the reduced need for promotion and awareness raising. The proposed plan to include the Scorecard assessments as part of the Victorian Energy Upgrades program which incentivises energy efficiency upgrades, is estimated to reduce the costs of assessment to between AU$180 and AU$240. This is roughly in line with earlier analysis of assessment costs for a proposed mandatory disclosure program in Australia which estimated assessment costs between AU$150 and AU$180 (with an alternative scenario of including a full thermal simulation as part of the assessment costing up to AU$784) (Allen Consulting Group, 2011).

As in the US, where programs are voluntary, this drives a different cost profile. Governments need to target awareness raising and subsidies to support assessments and upgrades. Research from the CRC for Low Carbon Living (Adams, Clark, & Potts, 2016) suggested that most households in Australia were not willing to pay more than AU$100 for a voluntary assessment.

Government administrative costs
There is a cost associated with house energy rating assessments themselves. This includes the resources required to establish a rating assessment scheme and any ongoing requirements for managing and maintaining the scheme. These costs were examined by Allen Consulting Group (2011), finding that mandating housing assessments at point of sale and lease generated a net benefit even if government costs were 50 per cent greater than estimated, for all options except the option requiring detailed plan drawings of homes. It was also noted that government administrative costs could be recouped in a mandatory program from a fee per assessment.

2.4.2 Benefits of assessments to the housing market

Key findings

The comparability, legibility, and wide acceptance of assessments is widely considered important in fostering action. There is value in energy efficient homes, incentivising upgrades. The research suggests that careful program design is essential to realise this potential.

- Assessments need to be trusted and considered useful by households.
- Assessments need to be available at point of sale and lease, with program design ensuring there is no ability to opt out at scale, especially for lower performing rental properties, to avoid negative impacts on social justice, with the real performance of lower quality housing becoming inapparent to the market and policy makers.
- Careful attention is made to ensuring assessments are clear and useful to householders and are understood broadly across the community.

Much of the literature has demonstrated a significant positive relationship between market value and home energy performance disclosure (Cajias, Fuerst, & Bienert, 2019; de Ayala, Galarraga, & Spadaro, 2016; Department of the Environment Water Heritage and the Arts, 2008; Franke & Nadler, 2019; Fuerst et al., 2013; Fuerst et al., 2015; Fuerst, Oikarinen, & Harjunen, 2016; Khazal & Sønstebø, 2020), whilst other researchers have found little or no relationship (Encinas et al., 2020; Hårsman et al., 2016; Murphy, 2014; Olaussen, Oust, & Solstad, 2017; Olaussen et al., 2019). For example, in Norway some researchers have found no market impact due to EPCs and consider that this could be due to the already high trust-based society, and lower quality of assessments in Norway (Olaussen et al., 2017; Olaussen et al., 2019), while others have found a significant positive impact (Khazal & Sønstebø, 2020).

In Australia, mandatory disclosure legislation in the ACT has been found to have a significant correlation between the house energy rating and price the market is willing to pay, with a premium of around three per cent paid for each additional star improvement in the rating, after all other factors such as age, location, and size have been eliminated (Berry et al., 2008; Department of the Environment Water Heritage and the Arts, 2008; Fuerst & Warren-Myers, 2018).

To determine the consequences of voluntary and mandated energy-efficiency disclosure, Fuerst and Warren-Myers (2018) examined precise information on property features in the ACT, and evaluated sales and rental transactions in the Australian housing market during a five-year period. The study assessed if home energy ratings (EERs) effect both property sale prices and rentals in the ACT, Australia's sole housing market with mandated EERs. The study findings show that claimed energy-efficiency levels, as well as other sustainability-related factors not included in the formal rating evaluation, have an impact. Rents and sales prices are heavily influenced by features such as heating and cooling systems, as well as the existence of solar power, because tenants and buyers are likely to estimate their predicted reduction in utility costs based on the EER.

The research also contributes to the discussion on the social justice aspect of residential energy efficiency by examining whether disadvantaged neighbourhoods and households are harmed by a lack of information and a scarcity of affordable energy-efficient stock. It notes however, that the non-disclosure rates of 50 per cent in the rental market continue to jeopardize the EER scheme's consistency as well as the market's perception of sustainability and energy efficiency.

In California, voluntary labelling through programs such as Energy Star, LEED for Homes and GreenPoint have be found to deliver an increased sale value of about nine per cent against comparable homes (Kok & Kahn, 2012). In another US study, a hedonic pricing model of more than 13,000 dwelling sales in Atlanta found that there was a premium for dwellings with an energy certificate of up to 11.7 per cent (up to USD$47,000 at the time of research compared to the average home sales price of USD$381,513) (Zhang, Li, Stephenson, & Ashuri, 2018).

In England, Fuerst et al. (2015) used a sample of 325,950 observations to measure EPC effects, revealing significant positive price premiums for dwellings with EPC ratings of A/B (5%) or C (1.8%) compared to dwellings rated D. For dwellings rated E and F, discounts were estimated at -0.7 per cent and -0.9 per cent respectively. In Wales a study of 192,000 dwelling transactions found even greater positive and negative premiums; with positive price premiums for properties with EPC bands A/B (12.8%) and C (3.5%) compared to houses in band D and for dwellings in band E (-3.6%) and F (-6.5%) significant discounts were found (Fuerst et al., 2016). Another study from England and Wales of more than five million residential property sale transactions estimated that being in a higher rating band improves the final sale price of a home by 0.8 to 2.5 per cent.

The researchers also found that EPCs homeowners who were just below a rating band were up to 11 per cent more likely to undertake energy efficiency investment prior to selling their property. Similar ranges of positive premiums (6.9%) have also been found for sustainable housing in Barcelona (7.8%) (Marmolejo-Duarte & Chen, 2019) China (6.9%) (Zhang, Liu, & Wu, 2017). In Flanders, a higher resale value of 0.075 per cent for each one per cent increase in EPC score have been found (Taranu et al., 2020).

Positive sale or rent value is not universally found in the research. For example, in Belfast, researchers found a complex relationship between sales price and EPC rating, with numerous variables and no clear causal relationship showing that higher ratings led to higher market value (McCord, Davis, McCord, Haran, & Davison, 2020). In Chile research has found that voluntary energy ratings negatively affected households willingness to buy (Encinas et al., 2020). More educated households valued ratings positively. The researchers suggested that results were driven by a lack of understanding and poorly communicated ratings with the solutions proposed including mandating ratings, improved communications, and subsidies.

There has also been qualitative research undertaken exploring the impact of the EPC on private purchasing decisions. For example, a survey of more than 1,200 households looking at purchasing decisions of existing houses in Germany revealed that the EPC had a minor impact (Amecke, 2012). The research found that program legislative design led to a lack of visibility of ratings, and the ratings were not consumer focused and informative, but these issues could be addressed with a program redesign. Others have found that a lack of understanding of house energy rating methods as a barrier (Taranu et al., 2020).

2.4.3 Outcomes

While there has been significant research exploring the impact on sale and rent value in the housing market from house energy rating assessments and information, there is less attention in the research to the actual changes in dwelling performance which resulted from any such assessments (Ali et al., 2020).

Sweden is one of a number of jurisdictions which had an early introduction of the EU EPC requirement with owners of multifamily dwellings required to obtain an EPC before the end of 2008 (von Platten et al., 2019). With the certificates lasting 10 years, there has been a significant number of dwellings in Sweden that have had a second rating completed. von Platten et al. (2019) have analysed the first and second round certifications and found that approximately 15 per cent of the certificates had substantial differences (e.g., to heated floor area), which meant they could not be compared. It was thought that some of the differences were due to some changes to the data collection process, but likely due to procedural differences between the energy experts issuing them (von Platten et al., 2019). However, for those dwellings where the certificates were valid for comparison there was still some data correction required due to a change in method. Importantly, the analysis between the two time periods found that energy performance in existing housing had improved and that improvement was greater in rental (private and social) rather than owner-occupied dwellings. Although, energy performance was initially less in rental housing and incentives for improvements were likely stronger.

In one study in the Netherlands (Murphy, 2014), only 10 per cent of the sampled cases showed clear evidence of the EPC information influencing the decision to purchase. In contrast, the information was found to be more useful post-purchase with 22 per cent of respondents noting that the EPC had influenced them to adopt or undertake some level of energy efficiency retrofit. While many reported that the information reinforced ideas about the energy efficiency measures they could take, 31 per cent stated they took more energy efficiency measures than planned as a direct result of the EPC information and 20 per cent took some activities they had not previously thought of.

Surveying homeowners across 12 EU countries Charalambides et al. (2019) found that EPCs did play a role in renovation decisions (and also rent/buy decisions) but that the results of the influence varied significantly across jurisdictions. The findings found that for those who had already renovated their homes, 59 per cent found the EPC played a very important role in undertaking the renovation, and 20 per cent said the EPC was somewhat important. However, this varied with almost a third of respondents from the UK saying the EPC was not important for their decision-making, suggesting that a wide variety of other market, supply, locational and contingent factors may complicate the relationship.

House energy performance data is also being used on a larger scale to understand overarching housing quality and performance and to help guide policy making. In Italy a study of more than 2 million EPCs found that over half of Italian buildings have very low energy performance, which corresponds to the energy ratings F and G (Pagliaro et al., 2021). These results are primarily related to the building stock's age (more than 60 per cent of buildings were constructed before the first energy regulation) and the limited number of new and renovated buildings (less than 10 per cent). Also in Italy, Attanasio et al. (2019) analysed 90,000 EPCs and attempted to automatically estimate the primary energy demand for space heating using data mining techniques. The researchers found that their proposed automatic calculation methodology (called HEDEBAR) was able to estimate energy demand with reasonable errors (~16% mean absolute percentage error) from drawing upon a small set of the dwelling features. However, the researchers do not say how quickly the analysis can be undertaken compared to a standard EPC evaluation or what size starting data set is required to validate data outcomes. Also, this approach would still require a home assessment by an independent expert for it to become valid as a housing assessment.

At an aggregate scale, policy makers are able to calculate impacts of home improvements. There have been significant performance improvements found from Canadian home ratings with evaluations finding that 70 per cent of households who received a house energy rating assessment reported they had implemented one or more of the recommended retrofits resulting in performance improvements of 10 to 15 per cent (Parekh et al., 2000).

2.5 Emerging opportunities for assessment tools

There is an increasing focus within the wider academic literature on emerging and potential future approaches and tools. There is recognition across this literature that while existing approaches have helped to develop improved knowledge around housing quality and performance, and in some cases helped to drive improvements to the existing housing stock, there are still limitations of the current approaches applied. Notwithstanding, this section is not based on evaluation of assessment tools but on speculations about future possibilities as context.

The inclusion of 'smart' data is one area of focus (Brown et al., 2021; Crawley et al., 2020; Jenkins et al., 2017; Pears & Moore, 2019). This includes the use of smart meter energy data which can provide a more nuanced data set on the actual energy consumption and occupant profile for the dwelling. It has been discussed that this data could be used to improve the efficiency (e.g. data can be collected and analysed off-site) and accuracy (e.g. when energy is consumed) of ratings and recommendations. Additionally, smart data could come from appliances which increasingly have 'smart' elements within them. This could provide further fine grain energy consumption data but also be used to identify appliances which are not working efficiently (Pears & Moore, 2019). Others have suggested that additional monitoring could be more easily included within a smart data system such as the collection of internal temperature data (Brown et al., 2021). It could also add to the development or a larger housing data set to inform housing quality and performance not just at a point in time but also longitudinally.

Jenkins et al. (2021) explored the role of using smart meter data to create thermal performance ratings and argue that using this data can provide a more accurate outcome for thermal performance of a dwelling. This approach could be integrated into existing EPC methods however they caution that there are some technical challenges including: ensuring that ratings remain independent of occupant behaviours/practices; and identifying which additional data inputs increase reliability and enable more informed retrofit decision-making whilst keeping the rating cost low and the calculation complexity tractable. The authors also reflected on the role of data such as from smart meters in delivering lower cost ratings and suggest that while in theory the use of data could streamline assessment processes that there was a trade-off between accuracy from a trained assessor and speed. To improve data driven evaluations more sources of data would be required which would add costs (e.g. for thermal sensors) and open up risks around the quality assurance of that additional data.

The use of new forms of data opens the possibility of machine learning to improve assessment and validation outcomes (Hardy & Glew, 2019; Khayatian, Sarto, & Dall'O', 2016). For example, Hardy and Glew (2019) imply that smart auditing criteria combined with machine learning could have the ability to improve EPC auditing methods by automatically correcting any inaccuracies discovered in the EPC record. Khayatian et al. (2016) machine learning is an appropriate tool for monitoring change over a large number of buildings and may be used to acquire a close view of various energy policy plans. The computation technique for energy certificate tools may be modified every few years to meet new energy efficiency rules. Others have found that there are also opportunities to link dwelling performance data into other available data sets to leverage analysis across a range of different opportunities and should be linked to longer term policy goals to help signal future pathways and drive innovation (Madrazo et al., 2018; Pasichnyi et al., 2019; Sunderland & Santini, 2021).

The 'Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness' project suggests some improvements for the EPC system including (Panteli et al., 2021):

- to evolve from point in time evaluation to a more dynamic rating, which could continue to refine recommendations or messages for occupants,
- the inclusion of real-time monitoring and actual performance data,
- recommendations for occupants which take more account of their personal needs rather than based upon an energy reduction metric,
- incorporate indicators that include environmental, financial, human comfort, and technological elements of new and existing buildings, with the goal of making building energy performance easier to grasp and providing a more comprehensive picture of actual building energy performance, and
- close the technology gap and enable the implementation of digital twin methods in calculating processes, utilizing the growing amount of building energy data from sensors, smart meters, and linked devices.

Additionally, Brown et al. (2021) note the following 25 key recommendations for the next generation of SAP/RdSAP in the UK:

1. SAP can and must become a tool for Net Zero Carbon ready new buildings.
2. SAP/RdSAP can and must become a better tool for whole house retrofit.
3. SAP/RdSAP can and must become better at evaluating energy use.
4. Homes need to become smart ready and SAP/RdSAP needs to help with this.
5. SAP can and must play a bigger role in reducing the performance gap.
6. Carbon factors: replace the short term with long term factors (e.g. 25-year average).
7. SAP should remain a steady-state monthly tool, but with a new module for flexibility.
8. SAP should 'tell the truth' and enable bespoke non-regulatory uses.
9. A significant improvement of Appendix Q and the PCDB process is required.
10. Overheating: towards a simplified 'flagging system'.
11. SAP/RdSAP outputs need to be compatible with disclosure and data analysis goals.
12. No more notional building: the introduction of absolute energy use targets.
13. New metrics for Net Zero Carbon (and not primary energy).
14. Better governance: a modular architecture and an evidence-based culture.
15. New EPC ratings from SAP/RdSAP to support Net Zero and fuel poverty objectives.
16. SAP should be fully integrated in the digital age.
17. Location should be taken into account and not normalised as it is now.
18. Domestic hot water should be modelled more accurately.
19. SAP/RdSAP should better model the energy performance of ventilation systems.
20. Thermal bridges: good practice should be rewarded (and bad practice penalised).
21. SAP needs to better reflect all energy uses, including cooking and white goods.
22. Occupancy: the standardised assumptions should be re-validated.
23. SAP/RdSAP needs to model all heat pump systems accurately to reward efficiency.
24. Heat networks: SAP/RdSAP should evaluate distribution losses more accurately.
25. Solar photovoltaics require better modelling and a prominent SAP/RdSAP output.

While these are focussed on the UK, those that are relevant may be adopted in Australia in principle providing that they reflect the objective and support the design of an assessment that is trusted, effective, and demonstrates efficacy. From the above list it is likely that recommendations 1-6, 11-23, and 25 would be most appropriate to consider in future assessment rating tools in Australia.

Notwithstanding these possibilities, it is clear that for the foreseeable future, onsite expert assessors will be required for housing assessments to pass the efficacy test and for outcomes to be used in transacting information, in databases, and in informing retrofit decision-making.

3 Australian housing stock data

This section presents a review of available data on the existing Australian housing stock quality and performance. This includes highlighting data gaps and limitations and implications for obtaining reliable independent data for households, industry stakeholders, and policy makers as part of the transition to a low carbon housing future. Table 2 provides a summary of the key data on Australian housing stock conditions with Appendix 2 presenting further information about the various datasets.

3.1 Data on existing housing quality and performance

There is currently no single data set of Australian housing condition and performance. However, a range of programs and projects have collected various information about housing condition and performance over the past 15 years. Table 2 provides a summary of these datasets.

Table 2 Summary of key Australian housing stock condition data.

Data type	Year	Location	Program/ project	Sample size and elements included
Appliance upgrade data	2009-ongoing	VIC	Victorian Energy Upgrades.	Mandatory program of incentives for upgrades. 2 million+ dwellings and 70 million certificates across retrofit activities including lighting, hot water systems, heating and cooling, weather sealing, in-home displays, appliances and more.
BASIX	2011 - ongoing	NSW	BASIX dwelling certificates 2011-2020.	Mandatory program for new and renovated homes. 777,000 primarily new or renovated dwellings. Energy consumption including lighting, hot water systems, heating and cooling, ventilation, pools and spas, alternative energy sources and other energy uses.
Performance data	2015	All states	House Energy Efficiency Inspections Project.	Research. Evaluation of 129 Australian dwellings using energy surveys, thermal imaging, and blower door tests.
ABS	2015	All states	Residential Energy Baseline Study: Australia 2000-2030.	Modelling. Model of future energy consumption and appliance numbers for dwellings in Australia across 125 residential appliance products.
Monitored house data	2015-2019	VIC	Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses.	Research. 60 existing (pre-2005) class 1 Victorian dwellings. Retrofit activities included lighting, appliance upgrades, insulation, heating and cooling and more.
Performance data	2015	VIC	Home Energy Efficiency Upgrade Program.	Single project. 793 dwellings received a hot water system upgrade.
ABS	2016	NSW	NSW housing typology development project.	Research. ABS basic housing characteristics of NSW housing (2.4 million) and various surveys of housing attributes of ~15,000 dwellings.
NatHERS	2016-ongoing	All states	Australian Housing Data Portal.	Mandatory program for new and renovated homes 1.1 million dwellings including information on Star rating, design, materials, photovoltaics, and fixed appliances.
Performance data	2017 - ongoing	All states	Scorecard	Voluntary program ongoing. 6800 dwelling assessments (as of June 2022). Evaluation covers the building shell, heating, cooling, lighting, hot water, energy generation, spas and pools.
Self-reported data	2018	SA, VIC and NSW	The Australian Housing Conditions Dataset.	Research. 4,501 households. Survey covered topics such as tenure and accommodation, construction and maintenance of dwelling, energy, indoor environment and safety, quality and satisfaction, housing costs and financial strain, health status and demographics.
Self-reported data	2020	All States	The Australian Rental Housing Conditions Dataset.	Research. 15,004 rental households. Collected information across the characteristics of lease arrangements, dwelling condition and quality, the affordability of rental payments and other financial hardship, the presence of major building problems and maintenance needs, future housing aspirations, and whether the dwelling supported tenants' security, safety, and wellbeing.
Performance data	2022	VIC	Healthy Homes Program.	Research. 1,000 dwellings which are evaluated pre and post retrofit across energy use and bills, energy efficiency, thermal comfort, health and wellbeing.

Overall, the information available on new home performance is substantial, whilst limited information is available on existing homes, which make up the majority of Australia's housing stock.

The introduction of NatHERS in the early 2000's represents a significant step forward for the type of information available for new housing. The NatHERS certificates include the overall star rating, the dwelling National Construction Code class, floor and window areas, dwelling zones, construction materials of walls, floors, roofs, windows and insulation, and some limited information around photovoltaics, hot water, and air conditioning systems.

There are now more than 1.1 million dwellings which have a NatHERS rating including 1,059,000 new dwellings and 50,000 existing dwellings. Approximately 90 per cent of new dwelling approvals in Australia are captured within the portal (with the other 10 per cent of dwellings achieving approval via alternate approval approaches). Therefore, there is a detailed and growing data set of newer housing in Australia. The portal provides significant public access to the overview data collected and can provide information from the national to postcode level and across a range of different building elements (e.g. materials, star rating). CSIRO can extract further information than is provided on the public portal having access to all data submitted as part of the NatHERS approval process and can present information for both new build and existing housing.

There are a number of other projects and data sets which have collected information on existing housing conditions. A key study which is often referred to within the wider academic literature is the longitudinal retrofit assessment research conducted by Sustainability Victoria in 2015 (Sustainability Victoria, 2019). The Sustainability Victoria research focused on existing houses that were built pre-2005 and undertook a series of retrofit interventions to evaluate their outcomes. Across a sample of 60 existing class 1 dwellings an initial NatHERS assessment rated the dwellings as an average of 1.8 Stars. However, this varied across the sample with older dwellings (pre 1990) achieving an average of 1.57 Stars while houses built between 1990 (after minimum insulation requirements were introduced in the NCC) and 2005 achieved an average of 3.14 Stars (Sustainability Victoria, 2019). This data is presented in a series of reports and access to the raw data would need to occur via Sustainability Victoria.

Other research from CSIRO analysed the condition of recently constructed dwellings by evaluating airtightness and insulation quality for a sample of 125 existing houses (up to 10 years old) assumed to have been built to a 5 or 6 Star minimum (Ambrose & Syme, 2015). The results demonstrated that the airtightness levels varied significantly. While the overall average air change rate was 15.4 ACH@50Pa, half the houses tested were above 15 ACH@50Pa which is considered the upper mark for a newly constructed house in Australia. In addition, there were a small number of houses (approx. 11) which recorded air change rates above 30 ACH@50Pa which would be expected in old poorly sealed dwellings but not newer construction which indicates significant quality issues in the housing stock. In terms of the insulation installation quality, it was found to be average in 39 per cent of homes and poor in 10 per cent of homes, with prominent gaps around openings, pipes and the like or missing insulation in some locations causing poor outcomes.

The Australian Housing Conditions Dataset (Baker et al., 2019) is another recent data set which has collected a range of dwelling and occupant data to understand the condition of the Australian housing stock. The dataset contains 4,501 randomly selected households from South Australia, New South Wales, and Victoria. Data was collected via telephone interviews so was self-reported data by the household rather than a detailed expert assessment of the dwelling. Building upon this data and approach the Australian Rental Housing Conditions Dataset has been established in recent years and collects self-reported data for the housing quality and conditions across the rental housing sector, with more than 15,000 participants to date (Baker et al., 2022). The Australian Rental Housing Conditions Dataset is intended to be a longitudinal study which will help provide a data set about rental housing condition over time.

There are also a range of other stakeholders who collect and report on various data about the housing industry. For example, CoreLogic and Oxford Economics capture data around housing affordability and some elements of a dwelling such as appliances. However, there is limited data collected on overall housing energy and thermal performance within these wider data sets. Data that is not collected by skilled assessors remains unvalidated and subject to a range of quality control issues.

3.2 Implications of available data

To date there has not been a national approach, or project, to collecting data on Australian housing quality and performance. Information about housing quality and performance in Australia has been informed from a number of different programs and projects attempting to collect various data on dwelling quality and performance. The lack of validated and consistent data hampers policy development. The current ad hoc approach is less persuasive to develop larger scale policy development, responses (e.g. retrofit) and household knowledge and action, the data itself is limited in scale, scope, consistency and reliability which likely reduces the opportunities to improve housing outcomes.

The NatHERS data collected by CSIRO represents the largest data set and has been important for establishing the current state of the new housing market. The NatHERS data could also be useful for tracking the materials and technologies which are being used within the industry and this can help with guiding the industry towards different outcomes (e.g. from single to double glazed windows). This is not just for new housing but also existing housing which undergoes a NatHERS assessment. As the data base on NatHERS assessments for existing housing grows, there is an opportunity that the data provided for existing housing to be used to understand the wider current state of play for existing housing. However, this data is only likely to be useful at a high level given the data would not be representative of the wider existing housing stock, moreover, at the individual dwelling scale, each assessment requires validation with on-site inspection.

A limitation of design-based modelling is that the information is based upon proposed design and not the constructed dwelling meaning that there may be differences between the planned and actual dwelling data. Therefore, the data is a proxy rather than an actual outcome. The data is also limited in its ability to identify weak points within housing performance such as with thermal bridging or airtightness. In order to find this type of data it requires assessors to use post construction assessment and blower door test or thermal imaging; both of which take time and resources to do properly.

Verified real performance (or as-built) data on existing dwellings is largely limited to a series of smaller scale research projects and do not cover all elements of energy use within a dwelling. This lack of verified data not only impacts on understanding of individual dwelling performance but limits the ability to inform policy or approaches to improve outcomes.

For households this means there is a lack of detailed and reliable information at an individual dwelling level in Australia. As presented above, there is evidence that reliable information about dwelling quality and performance can influence purchase and rent decisions, and guide retrofit activities. Without that information, there is a high likelihood that households are not making informed decisions.

Overall, the lack of a robust, reliable and verified data set on housing energy performance in Australia is likely to be limiting the opportunity for improving housing outcomes. This once again points to the idea of building a large database of actual observed and evidenced assessments.

4 Practical implications for design parameters

The report has reviewed and analysed literature on housing energy assessments to inform principles, parameters and specific data availability and needs underpinning an effective and trusted assessment program. The review of literature and analysis of housing assessment tools (Section 2) and the review of Australian housing stock data (Section 3) together provide valuable insights into the state of, and prospects for, housing assessment in Australia. Housing assessments that are to be used in transactions and to inform retrofit must demonstrate efficacy. In this section, by drawing upon the earlier analysis, design parameters for a simple, user friendly, least cost, optimised home energy assessment approach that produces the required verification, reliability and independence are proposed. These are summarised in Table 3 below, where each of four objectives of a model housing assessment tool are proposed, each with its own set of parameters.

The objective of this analysis is to support policies such as minimum building standards, public disclosure of housing assessments for buyers, renters and policy makers, social norming, or broad scale housing stock assessment, primarily focusing on existing homes. This requires a consistent, standardised, objective, trustworthy, transparent, validated approach. This research on best practice approaches has been summarised in the following table.

Table 3 Design requirement recommendations for an optimised housing assessment tool suited to public transactions.

Design requirement objective	Key requirement	Recommendation
Accurate and Holistic The assessment must reasonably assess what it intends to assess.	Reliable and certified by an expert assessor, seen as highly regarded, and accuracy not in question.	Requires an individual asset-based on-site assessment that is attentive to the specific dwelling given the diversity of stock, lack of consistent information to support modelling, and to account for modifications. Opportunities to use assumptions to generate higher ratings need to be avoided to support trust. Design for mechanisms to validate assessments data: • Standardised tool, training, and methodologies • Transparency • Field testing • Evaluation • Maintain assessments with up-to-date technologies • Program quality controls
Robust and Consistent The process of implementing the assessment must demonstrate integrity including both the way the assessment is undertaken and the results it produces.	Moderated and reliable output, i.e., repeatable and with low variance.	• Accredited, trained, and independent assessors, with accountability and warranty requirements • Consistent methodological approach nationally for consistent rating • Robust cost/performance estimation algorithms • Rating validity of maximum 10 years as per EU • Auditing assessments and assessors to improve quality and consistency of assessments as well as to inform improvements to tools and training approaches • Benchmarking and moderation of assessments
Applied and Clear The assessment must be applied and integrated into the sectors that it intends to influence and be able to be used, easily, by the people involved.	Produces a legible, accessible, intuitive rating summary page and symbol that has widespread recognition (like appliance labels).	• Home assessments broadly available at point of sale and lease, with requirements that the symbol is displayed prominently and clearly in marketing to influence market behaviour • Cognisant of relevant regulations such as the Australian Building Code and state planning and buildings approval processes • Opportunity for a minimum level of rated energy efficiency for existing homes • Mandatory programs need to minimise opportunities to opt out of assessments especially for lower performing rental properties, to avoid negative impacts on social justice • Assessments provide specific comparable information and upgrade suggestions for the home being assessed. Cover cost, energy, carbon and rating related to comfort (liveability, health and wellbeing) • Housing assessment scales ensure most house forms have a plausible path to improve ratings • Communities supported with translations and local assessors for an inclusive program • Ensuring assessments generate upgrades as a primary focus, reducing cost is a secondly priority • Assessments should be credible (skilled assessors) and persuasive (robust transparent tool) • Ensure the public is aware of assessments, their benefits, and can access assessments routinely at point of sale and lease

Design requirement objective	Key requirement	Recommendation
		• Ensure the diversity of households is supported with a specific focus on programs for social equity
Transparent and Adaptive The process must build trust with key stakeholders and reflect the changing context associated in relation to housing.	Open data and algorithm, with regular upgrades/updates.	• Data entered into a standardised tool supported by standardised data entry procedures, to generate assessments and upgrade options • Data collection standardised, objective, avoiding subjective data (such as specific householder behaviour or unfixed appliances) • Assessment methodologies and assessments transparent, piloted and tested in a wide variety of real homes and climates • Assessment program regularly evaluated to ensure the outcomes are being achieved in homes • New technologies regularly included to provide accurate upgrade suggestions Updates to be considered on a rolling basis in response to: • new technologies that measure energy consumption e.g. smart meters • new technologies to improve asset performance e.g. heat pumps, renewable energy technologies • new technologies associated with appliances • benchmarks of improved housing performance e.g. Flanders adding an A+ to the rating for dwellings that are energy producers • data attained of household use, housing type and tenure

The design requirement objectives in Table 3 are derived from the preceding work as follows. Firstly, there is a need for clear, practical information for homeowners to inform their retrofit investment decision-making. Second, in order to address market failures such as principal-agent and information asymmetry problems, there is a need for a tool with sufficient functionality and efficacy that outputs can be used in contractual contexts, e.g. sale or lease situations.

Third, the housing stock review reveals important gaps in our knowledge of the condition and retrofit potential of Australia's housing stock. This stems from lack of sufficiently detailed data to represent the diverse stock and the results of previous renovations and retrofit for energy efficiency in particular. In the absence of an integrated and sufficiently detailed picture of the stock condition, policy ambitions on climate change mitigation and on housing standards and a set of broader health and wellbeing objectives all remain at risk of being either ineffective or inefficiently configured. A housing assessment rating, administered broadly and consistently, is a means to provide the necessary information to address this risk.

Fourth, there is an objective around functionality that supports sufficient confidence in energy and carbon benefits that can enable evidenced savings to be transacted in various ways, e.g., in contributions to long term policy targets. A range of beneficiaries (e.g., purchasers and vendors of credits, energy service companies), their agents, e.g., policy stakeholders would need to be able to understand and use such information.

As discussed in Section 2, the body of evidence suggests that a broadly applied single tool/platform/rating tends to provide the most visible, simple, and beneficial means to provide housing assessment. While these are not without challenges, the stand-out example is the approaches implemented under the mandatory Energy Performance of Buildings Directive in the EU. In contrast, for example, in jurisdictions with numerous voluntary tools (e.g., US) there tends to be relative market confusion, and low uptake and understanding. Such programs need to be supported with ongoing projects, incentives and marketing generating ongoing additional costs to delivery. This points to a single approach with multiple functionalities.

In order to be effective, this approach must demonstrate efficacy and effectiveness, such that it produces the intended outcomes of driving home upgrades, and assessments are trusted by all relevant stakeholders, from homeowners to renters, governments, non-government organisations, and housing, real estate, finance, and energy efficiency sectors. Further, assessments must be applied and integrated into systems and sectors that they aim to influence for example, from the embedding of prominently displayed assessments at the point of sale in real estate advertising to influence information asymmetry and address market failures; to effective and engaging material applicable to a home as part of a behaviour change program.

Overall, the design must demonstrate clarity in relation to what the assessment program aims to achieve, and the underpinned by integrity accepted by stakeholders:

- The assessment program must reasonably assess what it intends to assess, which is reflected in the quality of *accuracy*. If this is not achieved, and not accepted by stakeholders, the scope of the assessment program must be revisited.
- The rating and program must be *easy to understand* and *householder* focused, so it is applied and integrated into the sectors that it intends to influence and be able to be used, easily, by the people involved. This is essential because without addressing the needs of the community it will be ineffective and may impact negatively on social justice.
- The process of implementing the assessment must demonstrate integrity and this is reflected in the qualities of *trust.* The emphasis is on both the way the assessment is undertaken and the results it produces.
- The assessment must be *consistent* with low variability to be effective at influencing upgrades and to build trust with key stakeholders.

5 Conclusion

This report focuses on existing dwellings and on assessing energy efficiency and energy use during the occupation of a dwelling. It reviews housing assessment tools to this end, plus the state of play of housing condition databases in Australia, and proposes design parameters for optimising housing energy assessment.

The international literature review includes a wide range of housing energy assessment tools and approaches and summarises key findings from best practice (Section 2 and Appendix 1). A selection of seven assessment tools is also examined in more detail.

The review of available data relating to housing quality and performance of existing Australian housing stock draws upon complementary research to identify data availability and information gaps in national housing stock energy performance data (Section 3). The available data and associated data gaps are then discussed in relation to implications for Australian policy making, the housing industry and households, and the transition to a low carbon housing future.

Drawing upon the outcomes above, design parameters for an effective housing assessment must address the market failures identified and key opportunities presented (Section 4) and meet the objectives of the housing assessment.

Overall, there is a significant opportunity to improve the energy performance of housing in Australia, which would help drive the transition to a low carbon housing future, through the rollout of consistent, trustworthy, independently verified assessment information on energy performance of dwellings. This research established the four design requirement objectives for such a tool:

1. Accurate and Holistic
2. Robust and Consistent
3. Applied and Clear
4. Transparent and Adaptive.

The variability between dwellings means that a rating assessment such as that described here, is essential. Self-assessments, checklists, third party data, and bills-based estimators alone cannot meet the design parameters, and indeed, may provide misleading advice and even occupational health and safety risks. Moreover, trusted and verified assessments underpin participation and effectiveness. The legibility and trust garnered by the national appliance labelling system in Australia is one of the world's best examples of energy efficiency labelling. An equivalent for housing with similar levels of trust would drive commensurately high levels of participation.

The report provides 6 key recommendations:

1. In an era of triple threat; a changing climate impacting home comfort, an imperative to mitigate carbon emissions, and spiralling energy costs; energy efficiency retrofit should be a high-priority issue for policy makers, households, purchasers, renters, and providers of housing. The need for access to verified assessment information which is suited to a variety of needs from property transactions to informing large scale retrofit programs is justified on this basis. The research shows that such schemes, for example, EPCs in the UK, have a far higher take-up than voluntary schemes for private use such as the Home Energy Score in the US.

2. An accredited and trained assessor is required to facilitate accuracy and quality assurance, which are necessary for public programs to engender public trust and to be able to use the data in legal transactions. Appropriate monitoring and evaluation systems must be embedded in the assessment design. Variances in assessment outcomes (e.g. across Europe) demonstrate that accredited and trained assessors are essential alongside auditing to provide quality assurance.

3. Legal efficacy; in order to address market failures such as principal-agent and information asymmetry problems; requires a tool with sufficient functionality and efficacy that outputs can be

used in contractual contexts, e.g., sale or lease situations and financing. The literature recommends a range of methods to improve the accuracy of data so that dwellings within in a region receive comparable assessments.

4. The housing stock review reveals important gaps in our knowledge of the condition and retrofit potential of Australia's housing stock. This stems from a lack of sufficiently detailed data to represent the diverse stock and the results of previous renovations and retrofit for energy efficiency in particular. In the absence of an integrated and sufficiently detailed picture of the stock condition, policy ambitions on climate change mitigation and on housing standards and a set of broader health and wellbeing objectives all remain at risk of being either ineffective or inefficiently configured. A housing assessment tool, administered broadly and consistently, is a means to provide the necessary information to address this risk.

5. The need for sufficient accuracy across thousands of assessments that can be scaled across the housing stock and support sufficient confidence in potential energy and carbon benefits is necessary to enable evidenced savings to be transacted in various ways, e.g., in contributions to long term targets. A range of beneficiaries (e.g., purchasers and vendors of credits, energy service companies), their agents, and policy stakeholders, among other stakeholders, would need to be able to understand and use such information, and the information would need to be verified and independently produced.

6. Even in cases where assessment information is only required within households to inform investment decisions, there is a need for clear, practical, reliable and accurate information to inform energy use, upgrade options and potential savings.

6 Appendices

6.1 Appendix 1 – Housing energy assessments worldwide

Program name	Founding jurisdiction	Sector	Introduced	Mandatory/ voluntary
3CL (Calcul de la Consommation Conventionnelle des Logements) - Diagnostic de Performance Energétique	France	Government	2006	Mandatory
Reduced Data Standard Assessment Procedure (RdSAP)	UK	Government	2005	Mandatory
PN-EN ISO 13790 – Thermal performance of buildings – calculation of energy use for space heating and cooling	Poland	SAI Global Standards	2013 Superseded 2017	Voluntary
UNI 1130 – Energy performance of buildings – part 1: evaluation of energy need for space heating and cooling	Italy	SAI Global Standards	2014	Voluntary
Energy Star (home performance)	US & Canada	Government	2001	Voluntary
Energy Star (Home Advisor)	US	Government	Energy Star founded 1992	Voluntary
Home Energy Score	US	Government	2012	Voluntary
E-Scale (replaced HERS Score and HERS Index)	US	Government	2009	Voluntary
LEED for Homes	US	Not-for-Profit	Developed since 1993	Voluntary
National Green Building Standard	US	American National Standard	2008	Voluntary
Energy Performance Certificate	EU	European Union	2002	Mandatory
R-2000 (EnerGuide)	Canada	Government and NGO partnership	1991	Voluntary
Zero code	California	Architecture 2030 Building Energy Standard	2018	Voluntary
Healthy Homes Standard	New Zealand	Government	2019	Mandatory
Green Score	Singapore	Industry	2021	Voluntary
CEV	Chile		2012	Voluntary (although mandatory for social housing)
National Scorecard	Australia	Government	2017 (Victoria), 2020 (Australia)	Voluntary
ACT Mandatory Disclosure Program	ACT	Government	1999	Mandatory
Sustainability declaration	Queensland	Government	2009-2012	Mandatory
Household Energy Assessment Rapid Tool	Global	NGO (WHO)	2014	Voluntary
Puget Sound Energy	Washington, USA	Industry	1997	Voluntary
EnerWisely Home Energy Score	USA	Industry	2022	Voluntary
Mass Save®	Massachusetts, USA	Industry	NA	Voluntary
MyHEAT	Canada	Industry	2015	Voluntary
Community Home Energy Check	UK	NGO	NA	Voluntary
CU Greener Homes	Ireland	Industry	2021	Voluntary
HACKS calculator	Europe	Government	2021	Voluntary
Home Energy Yardstick	US	Government	Early 2000's	Voluntary - assessment
NYSERDA HPwES Program	New York,	Government	2015	Voluntary
NatHERS	Australia	Government	Early 2000s	Mandatory

6.2 Appendix 2 – Scope and approach of this research

DELWP contracted RMIT University in February 2022 to research housing energy assessments worldwide and housing quality and performance data in Australia, to consider practical implications for the design of effective house assessments in the Australian context.

This report, *'Optimising housing assessment to drive low carbon energy efficient housing upgrades'*, presents the outputs of the research. The scope includes a focus on existing dwellings and on evaluating energy efficiency and energy use during the occupation of the dwelling. It does not include wider lifecycle impacts of housing nor other sustainability elements such as water. Noting that house energy assessments are in common use by international organisations; national, state, and local governments; collaborations between governments such as regional authorities; utility companies; not-for-profit organisations; for-profit community organisations; and private companies, this report includes a focus on both government and non-government programs to consider best practice designs, and consider the learnings achieved from these many programs. The research presented was undertaken from February 2022 to January 2023 in three complementary stages.

Stage 1 - Review and analysis housing assessments

An international literature review was undertaken of relevant housing assessments. The review included academic literature, and 'grey' literature such as policy documents, program guides and industry reports. Key search terms of 'house energy rating', 'energy assessment', 'housing performance', and 'energy performance certificates' were used to search RMIT Library online academic databases including Science Direct, ProQuest, Scopus, SpringerLink and Web of Science. This search was cross-checked with a search of Google Scholar to ensure a comprehensive literature search was undertaken. Google Scholar was also used to identify literature that had cited key documents, which allowed the research team to 'track forward' for additional literature. An initial scan of the literature was then undertaken to filter out literature outside the scope of the project and to help identify key assessment tools from around the world. The result was over 140 documents, many of which have been referenced at the end of this report.

The review identified a wide range of housing energy assessments. These are discussed in Section 2.1, and have been summarised in Appendix 1 – Housing energy assessments worldwide. The review also identified a number of criteria associated with effective assessment tools and the complex relationship between these criteria, the objectives of assessments, assessment design, efficacy and perceived trustworthiness, and cost-effectiveness. These are summarised in Section 2.2. In Section 2.3, these criteria are applied to analyse a selection of nine assessment tools in more detail, selected to ensure inclusion of:

- a range of designs,
- well-established programs and innovative approaches, and
- information about their cost-effectiveness.

The more detailed analysis is summarised in *Table 1. Key housing energy assessments*. Findings from this inform the final stage of analysis.

Stage 2 - Review of Australian housing stock data

A review of available data relating to housing quality and performance of existing Australian housing stock was undertaken. This review drew up complementary research being undertaken for the RACE for 2030 Cooperative Research Centre to identify data availability and information gaps and explore the role of data in the 2030 decarbonisation pathway. The available data and associated data gaps were then discussed in relation to implications for Australian policy making, the housing industry and households and the transition to a low carbon housing future.

Stage 3 - Practical implications for design parameters

Drawing upon the outcomes of work packages 1 and 2, work package 3 highlights that the integrity of a housing assessment is such that the objectives are stated, and the assessment design meets these objectives and engenders key criteria.

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