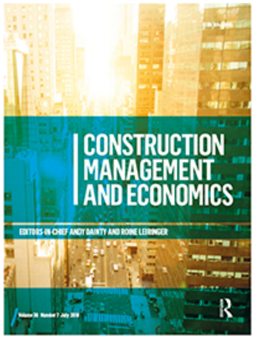

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Quantifying stakeholders' influence on energy efficiency of housing: development and application of a four-step methodology

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ABSTRACT

Identifying stakeholders' influence on project outcomes, prioritizing their importance and managing their interests accordingly is an effective strategy for maximizing benefits for organizations. Quantifying the influence of stakeholders on energy efficiency of housing allows for the development of an engagement plan that takes into consideration stakeholders' diverse goals, needs, levels of expertise, knowledge, authority, connectivity and closeness to decision-making processes throughout the different stages of the housing procurement. We present a theoretical approach for quantifying the influence of stakeholders on the thermal performance of housing. The quantification methodology builds on a number of stakeholder management approaches and is applied to Australian case studies for reflection and sense making. The quantification of the degree of influence is calculated by combining the rankings of stakeholders in six attributes that affect their influence on a building's energy efficiency outcomes. Quantifying human influence on buildings' energy efficiency can help future researchers and housing industry stakeholders in integrating the human aspect with technological, technical, economic and regulatory aspects to optimize the performance outcomes of energy efficient housing.

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Energy efficiency; housing; stakeholder management; sustainability

Introduction

A high reliance on mechanical systems to achieve thermal comfort is one of the main reasons behind the high energy consumption of households in Australia, with over 40% of average household energy consumption attributed to space heating and cooling, and over 60% of homes nationally using air conditioning (Australian Bureau of Statistics (Abs) 2010, 2014. Minimizing space heating and cooling demands through enhancing the thermal performance of the building envelope (referred to as "energy efficiency" throughout this paper), requires the implementation of a range of principles (such as building orientation, insulation, location and size of openings, materials specifications, etc.) during the building procurement stage (Mendler and Odell 2000, Lechner 2014). The implementation of these principles necessitates collaboration between multiple stakeholders, the integration of their tasks and the management of their relationships. This collaboration is a challenge, however, in an industry that is characterized by both researchers and government as having conflicted interests, lack of trust, short-term goals (Tzortzatou 2007), poor communication (Pitt&Sherry 2014), fragmented nature (Davis *et al*. 2010) and endorsement of a circle of blame (Crabtree and Hes 2009).

Freeman (1984) highlighted the importance of stakeholder management as a tool to manage human interactions in a manner that yields benefits to the stakeholders and enhances the outcomes of the activity they are involved in. It may present a useful approach for balancing the conflicted interests of the construction industry's stakeholders, and enhancing the energy efficiency outcomes for residential buildings. The purpose of this paper is to present the development of a stakeholder management methodology specifically for this application, and to test this methodology on a number of Australian case study homes.

Development and applications of stakeholder theory

Stakeholder theory was developed by Freeman in recognition of the role that players other than shareholders play in an organization's success. Starting from strategic management (Freeman 1984), the theory grew to include fields such as organizational management (Donaldson and Preston 1995), business ethics and sustainable development (Steurer 2006).

Freeman's initial theory defined stakeholders as "all of those groups and individuals that can affect, or are affected by, the enterprise" (Freeman 1984, p. 25). He

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classified stakeholders as internal (directly connected to the organization) or external (not directly connected, but able to affect an organization's outcomes). Definitions by other researchers include those who "have a legitimate claim over the firm" (Hill and Jones 1992, p. 133), those who have power to influence the organization (Frooman 1999) and those who have something to lose or gain from an organization (Clarkson 1995). Donaldson and Preston (1995) divided the literature theorisation into the descriptive aspect (an organization's characteristics and its behaviour with its stakeholders), the pragmatic aspect (identification of stakeholders' needs and impact on corporate self-interest objectives), and the normative aspect (ensuring stakeholders are given equal consideration for their satisfaction regardless of their impact on the corporate objectives).

Stakeholder management provides knowledge about the expectations, roles and needs of external and internal players who have the potential to either influence, or be influenced by a certain project/activity. This knowledge is an initial step in the analysis of stakeholders' impact on the outcomes of an organization, project, or activity (Freeman 1984, Bourne 2009, Wagner Mainardes *et al*. 2012).

Analysis of stakeholders includes two main steps. The first step is the classification of stakeholders based on their relationships with the organization and the role/s these stakeholders play. A review of the development of stakeholder classification strategies over time is summarized in Table 1, showing the evolution of the criteria used for classification and the resultant classifications. It shows differences in stakeholder classifications depending on whether the focus is on *the relationship* stakeholders have with an organization (e.g. Freeman 1984, Clarkson 1995, Fassin 2009), *the role* played by stakeholders (e.g. Callan *et al*. 2006, Vos and Achterkamp 2006, Turner 2006, 2014), *the direction of influence* (e.g. Bourne and Walker 2005, Ribeiro Soriano *et al*. 2012), stakeholders' *power and interest* (e.g. Mitchell *et al*. 1997, Johnson *et al*. 2008), or location in the communications network (e.g. Rowley 1997).

The second step in stakeholder analysis is the prioritization of their influence on an organization. Table 2 summarizes the literature relating to stakeholder prioritization, revealing the concepts behind each approach and the attributes used by various researchers for prioritizing stakeholders' influence. For instance, Mitchell *et al*. (1997) have prioritized stakeholders based on their possession of certain attributes. According to their research, stakeholders can be ranked by counting the number of attributes they possess.

The approach by Mitchell *et al.* has been criticized because it is based on the possession of attributes but does not distinguish the degree to which stakeholders may possess an attribute (Laplume *et al.* 2008). In response to these limitations, a number of researchers developed multidimensional matrices to attempt to quantify influence values. Examples of these include the *Power-Interest Matrix* of Scholes and Clutterbuck (1998), the *Knowledge-Support* and *Power-Impact* matrices of Turner (2006, 2014), and the *Stakeholder Circle* of Bourne and Walker (2005). Berardi (2013) applied Scholes' *Power-Interest Matrix* to identify barriers to adopting new sustainable technologies in a construction project. He found that stakeholders' power and interest is changeable throughout the stages of construction, and therefore proposed that a time dimension should be added. Taking a different approach to the concept of adding a time dimension, Yip Robin and Poon (2009) used the sustainable culture components of Blank and Wodarski (1997) to demonstrate shifts in the sustainability culture of stakeholders over the duration of a construction project.

Applying stakeholder management to energy efficiency outcomes of housing

Many researchers acknowledged the importance of stakeholder management as a tool to enhance construction projects' outcomes through balancing the conflicted interests of stakeholders, and encompassing their expectations and influences in the project management process (Jergeas *et al*. 2000, Olander 2007, Yang *et al*. 2009, 2011, Berardi 2013, Herazo and Lizarralde 2016). Applying a stakeholder management approach on the housing industry during procurement stages could potentially contribute to overcoming the characteristics that inhibit the thermal performance of housing, through analysing stakeholders' roles and impact on energy efficiency outcomes, and balancing their conflicted interests/goals based on their degrees of influence (Zedan and Miller 2016).

Stakeholder management could result in better implementation and development of energy efficient housing through:

(1) Managing the complex nature of the construction industry that is characterized by short-term goals, contrasting priorities, and late participation of players that inhibits the adoption of energy efficiency in housing (Chinyio and Olomolaiye 2009, Crabtree and Hes 2009, Berardi 2013).
(2) Assisting regulators in tailoring policies built on a better understanding of stakeholders' roles, interest, goals, and time of involvement, and on balancing stakeholders' objectives based on their degree of influence on energy efficiency (Ruggiero *et al*. 2014, Zedan and Miller 2016).

Table 1. Stakeholder management classification approaches.

Source	Criteria of classification	Classification
Freeman (1984)	Stakeholders' position inside or outside the organization	(1) Internal Stakeholders (2) External stakeholders
Clarkson (1995)	Stakeholders' presence or lack of contractual agreement with the organization	(1) Primary (with contract) (2) Secondary (without contract)
Vos and Achterkamp (2006)	Stakeholders' role within an organization	(1) Client (2) Decision-maker (3) Designer (4) Passively Involved
Turner (2006), Achterkamp and Vos (2008), Turner (2014)	Stakeholders' role within an organization	(1) Owner (2) Users (3) Sponsors (4) Resources (5) Manager
Callan *et al*. (2006), Achterkamp and Vos (2008)	Stakeholders' responsibilities within a certain project	(1) Controllers (2) Executors (3) Constraining advisors (4) Discretionary advisors
Bourne and Walker (2005)	Stakeholders' direction of influence and position inside or outside the organization	(1) Upwards (2) Downwards (3) Sidewards (4) Outwards
Fassin (2009)	Stakeholders' legitimate claim rights over the organization	(1) Stakeholders (2) Stakewatchers (3) Stakekeepers
Mitchell *et al*. (1997)	Number of attributes (power, legitimacy, urgency) possessed	(1) Low salient (2) Moderately salient (3) Highly salient
Savage *et al.* (1991)	Stakeholder's potential to threaten or to cooperate with the organization	(1) Supportive (2) Mixed blessing (3) Non-supportive (4) Marginal
Rowley (1997)	Social network analysis principles	(1) Commander (2) Compromiser (3) Subordinate (4) Solitarian
Leung and Olomolaiye (2009)	Risk event occurrence probability and the impact of that event on the organization	(1) Great danger risks (2) Probable catastrophe risks (3) Minor risks (4) Challenge risks
Johnson *et al*. (2008)	Stakeholders' degrees of power and interest	(1) Minimal effort (2) Keep informed (3) Keep satisfied (4) Key players
Ribeiro Soriano *et al*. (2012)	Stakeholders' influences over the organization and vice versa	(1) Regulator (2) Controller (3) Partner (4) Passive (5) Dependent (6) Non-stakeholder

(3) Developing strategies to increase the interest of influential stakeholders, or the influence of interested stakeholders in energy efficiency, since one of the main barriers inhibiting the implementation of sustainability in the construction sector is the low interest in it, or low power to enforce it. (Williams and Dair 2007).

(4) Quantifying and comparing the influences of stakeholders on the decisions of adopting innovative sustainable technologies into housing (Berardi 2013).

Table 2. Stakeholder management prioritization concepts and attributes.

Source	Concepts	Attributes of prioritization
Mitchell *et al*. (1997)	The salience of stakeholders is measured based on the number of attributes they possess. The salience is low for those who have only one attribute, moderate for those with two and high for those who have three	• Power • Legitimacy • Urgency
Savage *et al*. (1991)	Stakeholders with low potential to threaten but high potential to cooperate are considered supportive; those with high threat and co-operation are considered mixed blessing; those with high threat and low co-operation are considered non-supportive; and those with low threat and co-operation are considered marginal	• Potential to threaten the organization • Potential to cooperate with the organization
Rowley (1997)	Stakeholders do not only influence the organization directly but can indirectly influence it through other stakeholders	• Social network analysis principles/metrics
Scholes and Clutterbuck (1998)	Influential stakeholders are more likely to impact business activities. Constructive dialog becomes easier when there is an alignment of values between the company and the stakeholder group	• Stakeholders' potential to influence business outcomes • The impact of business activities on stakeholders • The alignment of stakeholders' values/purpose with the business goals
Johnson *et al*. (2008)	The degree of influence a stakeholder has over an organization is reliant on their interest in its outcomes, and power to impose changes to such outcomes	• Power • Interest
Berardi (2013)	Interest and power of stakeholders are affected by the time they become involved. Influence is identified using a three dimension matrix for measuring the changes in power and interest with time	• Power • Interest • Time
Bourne and Walker (2005)	Prioritization of stakeholders' importance is one of five steps that are followed to maximize the organization's benefits. It is done through calculating a numerical index that represents influence for each stakeholder, based on combining their ranking in a number of attributes	• Power • Proximity • Urgency (the weighted average of value and action)
Turner (2014)	Stakeholders influence is identified using a number of two dimension matrices to measure. Each matrix contains only two attributes	• Knowledge • Support • Agree • Power • Impact

Previous work

Our previous work in this area involved analysing relationship maps depicting both the process of housing design and construction in Australia and the relationships and information flows between the identified stakeholders (Zedan and Miller 2015). These stakeholders, in the Australian market, were identified based on the analysis of housing stakeholders' relationships map. This map was the product of a series of collaborative workshops initiated by an Australian state government authority in 2014. The workshops involved a number of housing industries and associated supply chain stakeholders. Stakeholders depicted in this map were chosen to be the subject of the analysis of this research.

Stakeholder classification and prioritization approaches summarized in Tables 1 and 2 were then examined in detail to evaluate the suitability of these approaches for specific application to the procurement stage of energy efficient housing (Zedan and Miller 2016). Table 3 summarizes this research, indicating the key attributes identified by the literature and the authors' re-interpretation of those attributes in terms of energy efficiency outcomes for housing. Potentially useful attributes and classification approaches are highlighted in Tables 1 and 3.

Some classification approaches were difficult to apply to energy efficiency as they were specifically developed for organizations. The classification approaches found to be applicable (highlighted in Table 1) were then grouped into an integrated model that shows how the energy efficiency stakeholders could be classified (Figure 1). Some of the attributes were not applicable (e.g. urgency does not apply to energy efficiency since it is rarely effected by the urgency of actions) or were too broad or too narrow to be applied (Zedan and Miller 2016).

Figure 1 and Table 3 show that the prioritization attributes found to be relevant to energy efficiency outcomes are distributed among a number of stakeholder management approaches. This suggested that a new integrated stakeholder management approach was needed to understand and manage energy efficiency's stakeholders.

The key attributes found to be relevant to energy efficiency (power, proximity, interest and time) (Zedan and Miller 2016), are consistent with the findings of Dair and Williams who identified "*key reasons for variations in the achievement of different aspects of sustainability*" (Dair and Williams 2006). These key attributes are explained in more detail below, as they are key to understanding the development of the new integrated approach.

- **Power**: Power is one of the most established attributes and is used in a number of stakeholder management approaches to analyse the influence of stakeholders on an organization's outcomes (Mitchell *et al*. 1997, Bourne and Walker 2008, Johnson *et al*. 2008, Berardi 2013, Turner 2014). Organizational power can be generated in three forms: (1) "positional" (where a stakeholder has the authority to continue/stop the project or reward/punish other stakeholders); (2) "personal" (where a stakeholder has influential personal traits such as having knowledge, expertise, being likable, persuasive etc.); and (3) "political" (where a stakeholder has high levels of connectivity with other stakeholders) (Yukl and Falbe 1991, Bourne and Walker 2005). Therefore, the broader understanding of the power attribute includes positional, personal and political power as sub-attributes. The "positional" power of energy efficiency stakeholders represents their legitimate authority to impose decisions that could influence energy efficiency. The "personal" power represents

Table 3. Analysis of prioritization attributes applicability to energy efficiency.

Source	Attributes	Attributes' applicability on energy efficiency (EE)
Mitchell *et al*. (1997)	Power	Power to enhance EE
	Legitimacy	Authority to impose EE
	Urgency	Not applicable since EE is not the result of urgent actions but rather pre-planned ones
Savage *et al.* (1991)	Potential threat	Threat could be caused by a range of factors (power, legitimacy, proximity, etc.). Therefore, it is too general
	Potential cooperation	Cooperation could represent interest or value, so it is covered by other attributes
Rowley (1997)	Social Network Analysis (SNA)	SNA could be used in conjunction with other attributes
Scholes and Clutterbuck (1998)	Impact on business	The power to enhance EE
	Impact by business	Value of EE to a stakeholder
	Shared purposes	Common interest in EE
Johnson *et al*. (2008)	Power	Power to enhance EE
	Interest	Interest in EE
Berardi (2013)	Power	Power to enhance EE
	Interest	Interest in EE
	Time	Timely involvement in decisions affecting EE
Bourne and Walker (2005)	Power	Power to enhance EE
	Proximity	Involvement in decisions affecting EE
	Value and action	Value of EE and willingness to take actions for its implementation
Turner (2006)	Power	Power to enhance EE
	Interest	Interest in EE
	Knowledge	Knowledge of EE principles

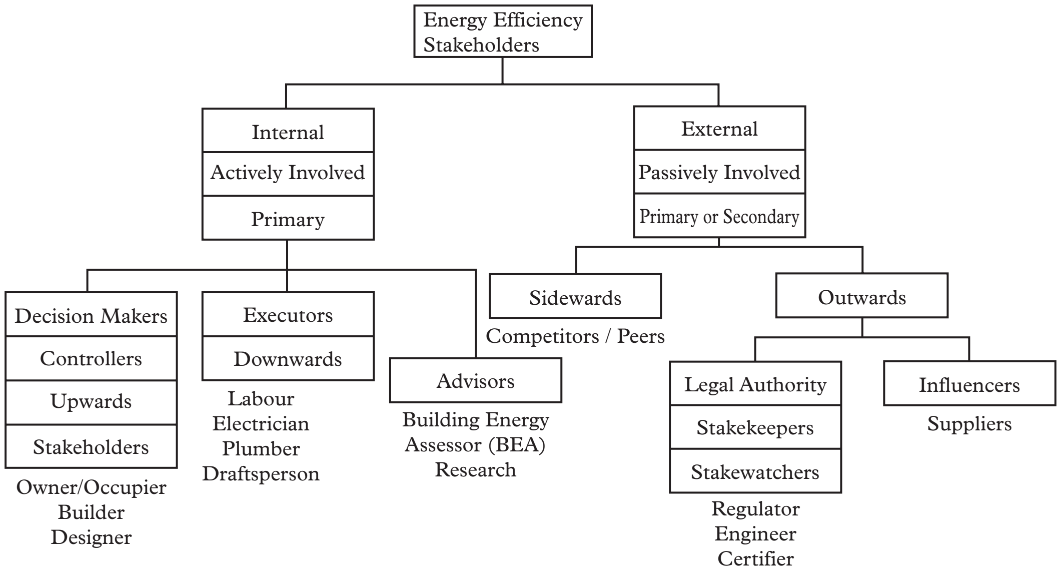

Figure 1. Integrated model of stakeholders' classifications.

their knowledge and expertise in the design and construction of energy efficient houses. The "political" power represents their connectivity with other influential stakeholders, since decisions that affect the outcomes of a certain activity might be influenced by stakeholders' relationships with each other (Rowley 1997, Prell *et al*. 2009, Romero *et al*. 2009, Ki Fiona Cheung and Rowlinson 2011, Zedan and Miller 2015). For instance, a well-connected stakeholder can obtain/pass information that could result in influencing others to make informed decisions.

- **Interest**: A number of researchers (Johnson *et al*. 2008, Bourne and Weaver 2009, Berardi 2013, Turner 2014) also suggested interest as an attribute that defines the importance of stakeholders. Interest in enhancing the energy efficiency of the house could have considerable effect on its realization. Stakeholders with low or no interest can treat energy efficiency as a low priority aspect and can influence other stakeholders to minimize their efforts to reach it. To identify the degree of influence, interest is divided into two sub attributes: value and action (following Bourne and Walker's (2005) division of urgency). When applying these two attributes to energy efficiency they can be understood as (1) the value a stakeholder gives to energy efficiency compared to other aspects of the house (such as the cost or number of rooms); and (2) the action the stakeholder is willing to take to ensure the implementation of energy efficiency (such as spending time, money, effort, etc.).
- **Proximity**: Bourne and Walker (2005) proposed proximity to the organization as one of the influence attributes. Reflecting on this attribute's influence on energy efficiency, proximity is re-interpreted as a stakeholder's involvement in decision-making and execution processes that could affect energy efficiency outcomes.
- **Time**: As mentioned previously, a number of researchers highlighted the importance of the time of involvement of stakeholders on the outcomes of construction projects (Pulaski *et al*. 2006, Williams and Dair 2007, Robichaud and Anantatmula 2010, Mollaoglu-Korkmaz *et al*. 2011). Early involvement and integration of stakeholders in the design stages: (1) enhances the decision-making process; (2) results in timely utilization of stakeholders' suggestions, knowledge and influence; and (3) increases the potential of reaching optimized outcomes of sustainability, overall performance, and costs (Berardi 2013). Therefore, other attributes such as power or interest could be rendered ineffective/irrelevant if stakeholders join the project at a late stage.

The time of involvement and its impact on the possibility of influencing energy efficiency is an attribute that is used to verify the significance of the influence produced by the three other attributes and their sub-attributes as explained above. This relationship of time, with each of the attributes, is shown in Figure 2.

Our analysis of the classification and prioritization approaches suggested that Bourne and Walker's approach could be used as the basis for integration with other

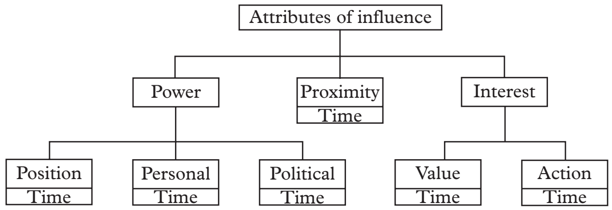

Figure 2. Attributes of influence on energy efficiency of housing.

approaches to develop a tool for managing energy efficiency's stakeholders, since this approach covers most of the relevant classifications and prioritization attributes. Bourne and Walker's (2005) method for prioritizing stakeholders is based on a numerical measurement of their influence that is generated from ranking their power, proximity, and urgency (which is the weighted average of value and action). Table 4 summarizes the rankings (from a scale of 1 to 4 for power and proximity and 1 to 5 for value and action) used by Bourne and Walker for measuring stakeholders influence (Bourne and Walker 2008, Walker *et al*. 2008).

The methodology we are presenting, further develops Bourne and Walker's method to solely focus on energy efficiency through: (1) reinterpreting the attribute rankings in a manner that concentrates on evaluating stakeholders' relation to enhancing/decreasing energy efficiency of housing; (2) adding other relevant attributes that were introduced by other approaches such as knowledge (Turner 2006) and time (Berardi 2013); (3) clarifying the concept of power in relation to influence on energy efficiency; and (4) giving a numerical value to influence based on Bourne and Walker's equation but with the effect of time taken into consideration as suggested by Berardi (2013).

Methodology

The methodology presented in this paper comprises four stages to quantify and compare the influence stakeholders have on energy efficiency:

Stage One: Quantifying the degree of connectivity (political power) of stakeholders.

Stage Two: Identifying the level of power of each stakeholder.

Stage Three: Ranking the power, proximity, and interest of stakeholders.

Stage Four: Quantifying the influence.

Stage one: quantifying the degree of connectivity

To quantify the degree of connectivity of stakeholders, a social network analysis approach (Loosemore 1998, Newman 2010) has been used to analyse the networks of communications between the stakeholders of each case study to identify the degrees of centrality and connectivity of each stakeholder within the network. There are a number of centrality metrics to understand stakeholders' influence within the network. Some of the common metrics are (1) degree centrality (number of links with others); (2) betweenness centrality (number of other stakeholders passing through a certain node (stakeholder) to reach their shortest path); (3) closeness centrality (the sum of the shortest paths between a stakeholder and every other stakeholder in the network); and (4) eigenvector centrality (the degree of connection to other influential stakeholders) (Loosemore 1998, Newman 2010).

The eigenvector centrality is the metric used to quantify the potential of connectivity of each stakeholder. It is

Table 4. Bourne's approach ranking criteria (Bourne and Weaver 2009).

Attribute	Ranking explanation	Attribute	Ranking explanation
Power	4- High capacity to formally instruct change: can have the work stopped	Value	5- Very high: has great personal stake in the work's outcome (success/ cancellation)
	3- Some capacity to formally instruct change: must be consulted or has to approve		4- High: sees work's outcome as being important (benefit or threat) to self or organization
	2- Significant informal capacity to cause change: capacity to cause change		3- Medium: has some direct stake in the outcomes of work
	1- Relatively low levels of power: cannot generally cause much change		2- Low: is aware of work and has an indirect stake in work's outcome
			1- Very low: has very limited or no stake in work's outcome
Proximity	4- Directly involved in the work: team members working most of the time	Action	5- Very high: self-activated, will go to almost any length to influence the work
	3- Routinely involved in the work: part time team members		4- High: is likely to make a significant effort to influence the work
	2- Detached from the work but has regular contact with, or input to, the work process.		3- Medium: may be prepared to make an effort to influence the work
	1- Relatively remote from the work: does not have direct involvement with processes		2- Low: has the potential to attempt to influence the work
			1- Very low: is unlikely to attempt to influence the work

chosen because of its potential to give a summary statistic of the stakeholders' centrality using a weighted mean based on each stakeholder's position in the network, connectivity to other stakeholders, and every stakeholder's importance, rather than using a simple sum or average (Borgatti and Everett 2006). The metric represents the relation between energy efficiency and the power of being connected to influential stakeholders in the network (to receive and distribute information that can influence decisions made by important well-connected players). This is explained in Equation (1) (Newman 2008) showing that the centrality of i (x_i) is proportional to the average of the centrality of its network's neighbours.

$$x_i = \frac{1}{\lambda} \sum_{j=1}^{n} A_{ij} x_j \tag{1}$$

Equation (1): Eigenvector centrality equation

where λ is a constant and A is the adjacency matrix ($A_{ij} = 1$ if i is linked to j and 0 if not).

Stage two: the power equation

Table 5 shows how each stakeholder is ranked within each of the power sources. The stakeholder's connectivity is ranked based on the degree of the eigenvector centrality into high, medium or low (through dividing the total range from 0 to 1 into three ranges equally). The knowledge is ranked based on the scope of work of stakeholders. The ranks differentiate between stakeholders whose scope of work is to manage multidisciplinary impacts on energy efficiency (e.g. designer, energy assessor); stakeholders who have experience in one discipline, but no understanding of other disciplines' impact on energy efficiency; and stakeholders with experience in a discipline that has no impact on energy efficiency. The authority is determined based on the stakeholder's entitlement to make certain types of decisions. The overall power is calculated using Equation (2), where any power source is allocated a value of 3 for high ranking, 2 for medium, and 1 for low.

$$P = (P1 + P2 + P3)/3 \tag{2}$$

Equation (2): Power to implement energy efficiency

where P = Average power, $P1$ = Position power (formal authority), $P2$ = Political power (communication and information), $P3$ = Personal power (Knowledge). The average power is used as one of three attributes that are ranked to collectively quantify the influence of stakeholders on energy efficiency.

Stage three: rating the three main attributes

The three main attributes of stakeholders' influence used by Bourne and Walker (2005) (Table 4) were reinterpreted in a manner that focused on their influence on energy efficiency outcomes of housing rather than the collective outcomes (e.g. cost, quality, time of construction, etc.). Table 6 explains the rankings of each attribute based on the reinterpretation that fits the relationship between stakeholders and energy efficiency. Applying both the original approach and the reinterpreted one on the same case study, showed that the reinterpreted one delivered results that reflect the importance of stakeholders to energy efficiency. For instance, the original approach showed that the owner has the highest importance (which is true if the evaluation is for the influence on the house outcomes as a whole). Alternatively, the reinterpreted one showed that the contractor has the highest importance (due to his high involvement in the design, choice of materials, onsite supervision, energy efficiency training, and interest in energy efficiency, unlike the owner who had low involvement in the decision-making and low interest in energy efficiency).

Stage four: quantifying the influence

The relative rankings of the attributes are shown in Table 6 (the numbers preceding the degree of a certain attribute). As action and value are sub-attributes of interest, these values are first added and divided by 2 (Equation (3a)) to give a value for interest. Equation (3b) is then used to calculate a stakeholder's influence on energy efficiency, multiplying the sum of the attributes (power, proximity and interest) by time.

Table 5. Ranks of Power sources.

Sources of Power	Position (Authority)	High: Decision-maker (budget setting, legal authority, etc.) Medium: Decision-maker under supervision of other stakeholders Low: Stakeholders following instructions
	Personal (Knowledge)	High: Understanding of how different disciplines/fields affect energy efficiency Medium: Experience in a discipline that could impact energy efficiency Low: Experience in a field that does not influence energy efficiency
	Political (Connectivity)	High: Eigenvector centrality value between 0.65 and 1 Medium: Eigenvector centrality value between 0.35 and 0.65 Low: Eigenvector centrality value between 0 and 0.35

Table 6. Ratings of influence attributes.

Influence attributes			
		Interest	
Power	Proximity	Value	Action
4- **High**: $2.7 \le p \le 3$	4- **Directly involved** in decisions that could impact energy efficiency	5- **Very high**: Energy efficiency is the main priority, has great personal stake in achieving it (e.g. the main goal is to build a 10 star house)	5- **Very high**: Self-activated, will go to almost any length to enhance energy efficiency (e.g. willing and capable of paying any cost to enhance energy efficiency)
3- **Medium**: $2 < p < 2.7$	3- **Routinely involved** in decisions that could impact energy efficiency	4- **High**: Energy efficiency is among the top priorities (e.g. the goal is to build an affordable energy efficient house)	4- **High**: Likely to make a significant effort to enhance energy efficiency (e.g. prefers to balance between energy efficiency and other aspects)
2-**Low**: $1.4 \le p \le 2$	2- **Detached** from decisions that could impact energy efficiency but has regular contact with, or input to, the work process	3- **Medium**: Energy efficiency is a secondary priority (e.g. the goal is to build a house with a view even if it means lowering energy efficiency)	3- **Medium**: Maybe prepared to make an effort to enhance energy efficiency (e.g. willing to enhance energy efficiency only if it is convenient)
1-**No power**: $1 \le p < 1.4$	1- **Relatively remote:** does not have direct involvement in decision-making or with processes.	2- **Low**: Energy efficiency is not a priority (e.g. energy efficiency is only considered if it does not affect other goals)	2- **Low**: Has the potential to attempt to enhance energy efficiency (e.g. can influence energy efficiency but not willing to)
		1- **Very low**: Energy efficiency is not a goal (e.g. energy efficiency is not considered even if it does not affect other goals)	1- **Very low**: Unlikely to attempt to enhance energy efficiency (e.g. incapable and not willing to influence energy efficiency)

$$U = (a + v)/2 \quad (3a)$$

$$I = T(P + Pr + U) \quad (3b)$$

Equations (3a) and (3b): Influence on energy efficiency

where I = Influence score, P = power, Pr = proximity, U = interest, a = action, v = value, and T = time factor.

As stated earlier, a number of researchers acknowledge that stakeholders' influence is better utilized at the early stages of decision-making (Pulaski *et al*. 2006, Williams and Dair 2007, Robichaud and Anantatmula 2010, Mollaoglu-Korkmaz *et al*. 2011, Aapaoja *et al*. 2013, Berardi 2013). Paulson (1976) developed a curve showing that the influence of stakeholders on the cost of a construction project decreases as the project progresses. He argued that the capability of influence is 100% prior to the design stage and is reduced to reach only 25% by the beginning of the construction stage. Macleamy (2004) supported this argument through developing the Macleamy curve. He suggested that stakeholders should follow an integrated project delivery (IPD) and increase their informed decision-makings efforts at an early stage of the project. Based on Macleamy and Paulson curves, the time/energy efficiency influence curve (Figure 3) is developed as a scale to calculate the time factor, which affects the overall influence of stakeholders on energy efficiency depending on the time they became involved in the project. The curve shows a reduced decrease in influence with time than the curves addressing influence on cost, since changes in the costs and expenditures of projects is more rigid than implementing energy efficiency. For instance, decisions such as adding insulation could be made during the construction stage and could have a significant influence on energy efficiency (Friess *et al*. 2012, Fang *et al*. 2014). Similarly, user behaviour and utilization of energy efficient appliances during occupancy

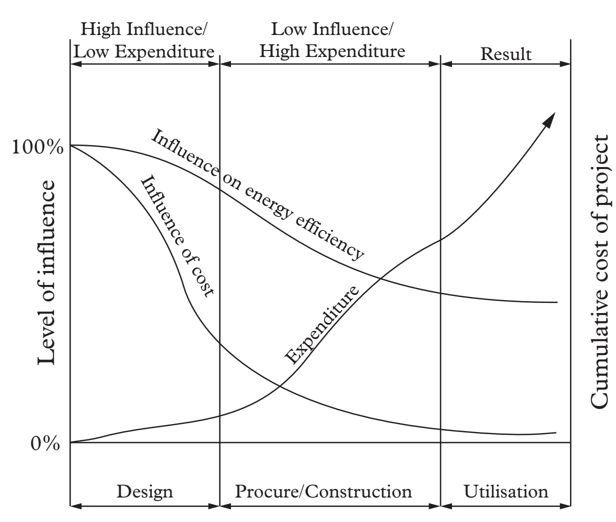

Figure 3. Levels of influence on cost and energy efficiency.

can significantly influence energy efficiency (Andersen *et al*. 2007, Pilkington *et al*. 2011). There is a margin for adjusting the time factor depending on the degree of flexibility of stakeholders to change in the latter stages of procurement. For instance, if the owner has restrictions against any changes being made after the design stage is completed, the time factor could be changed to zero to completely cancel the influence of stakeholders who join the project after the design stage. Therefore, the time factor scale (Figure 3) should be used as a guideline that could be adjusted for each project differently after discussing the degree of flexibility that "manager stakeholders" hold for changes throughout the different stages of construction.

Application of methodology on case studies

The four-stage methodology was applied to stakeholders of six energy efficient, owner-occupied housing case studies in Australia (Table 7) to demonstrate the application of the methodology and show how the differences in the attributes can be understood in relation to actual practice.

Table 7 shows that four of the houses used insulated structural panels (SIPs) as the main construction/external walls materials. These four case studies used a traditional procurement method where the owner developed the design, then contracted the contractor for the construction phase. House 5 is an existing house that was retrofitted by its owner to be energy efficient (the labour were hired and supervised directly by the owner), and house 6 was initially built as an energy efficient display home by its owner/contractor who supervised it closely throughout the different stages of procurement.

The owners of houses 1, 2, 3, and 4 designed their houses with the help of a draftsperson. The owner of house 1 is a professional architect, who designed the house specifically to be energy efficient, but still contracted a draftsperson to develop the construction drawings. The owner of house 5 (who is a construction management and conservation expert) designed the renovations, while the owner of house 6 contracted a professional architect to design the house to be energy efficient.

Semi-structured interviews were selected as the methods for gathering data to rank the attributes. The interviews took into consideration the theories of planned behaviour (Ajzen 1991) and theory of behavioural change components (Blank and Wodarski 1997). Considering these theories helps separate between the passive and active stages of behaviour. The interview questions focused on information that could help rank each of the six attributes discussed earlier. Table 8 shows the types of questions used to give rankings to each of the attributes for each stakeholder. It is important to note that while other researchers could replicate the overall methodology (the four steps), the method

Table 7. Case studies data.

	House 1	House 2	House 3	House 4	House 5	House 6
Construction type	SIPs	SIPs	SIPs	SIPs	Brick veneer	Timber
Type of windows	Double glazed	Single glazed U-value = 5.55	Double glazed U-value = 4.8	Double glazed U-value = 2.36	Single glazed U-value = 6.57	Single glazed U-value 4.7 Timber Louvers
Owner's other roles	Designer	Designer	Designer	Designer/ Construction supervisor	Designer/ Construction supervisor	Contractor
Owner has experience in sustainable construction	Yes (professional architect)	No	No	Yes	Yes	Yes
Contractor SIPs training	No	No	Yes	No	Not SIPs	Not SIPs
Followed traditional procurement	Yes	Yes	Yes	Yes	No	No
Energy efficiency is the main goal	Yes	No	No	Yes	Yes	Yes
Owner' Motives behind building energy efficient house	Lowering the operational costs			Minimizing energy consumption to lower the environmental footprint	Quality of life/ lower operational costs	Proving that a traditional house could be energy efficient
Solar panels installed	Yes	No	Yes	Yes	Yes	Yes

Table 8. Interviews questions relation to influence attributes.

Attributes	Questions aims to identify
Personal power	• The degrees of awareness, concern, knowledge, and expertise that stakeholders have • The degree of awareness about the need for energy consumption mitigation, and the role of houses in enhancing such mitigation • The level of any background knowledge related to energy efficient construction, understanding of sustainable housing, and its relation to decisions made by stakeholders
Position power	• The process of procurement, relationships between stakeholder, the contractual agreements, hierarchy of authority and supervision, roles and responsibilities played by each stakeholder, types of consultation made to external or internal parties, and possible barriers to decisions
Political power	• Each stakeholder's links with the rest of the stakeholders, and their possession of information (interviewees were asked to fill in a template of the housing stakeholders' network)
Proximity	• The degree of involvement in decision-making
Value	• The level of priority of energy efficiency compared to other aspects such as cost or design, view etc. • The motives of building/living in an energy efficient house (personal, social, economic, environmental, etc.), and the benefits of an energy efficient house
Action	• The willingness to spend time, money, effort, etc. to achieve energy efficiency • The barriers preventing the owner/contractor of building more sustainable housing and their attempts to overcome these barriers • The energy-saving features utilized in the house and their cost, ease of supply and installation
Time	• Identifying the stages where stakeholders took decisions related to energy efficiency, and the stage that each stakeholder became involved in the project

used to collect the data needed for ranking the attributes could be different depending on the resources of other researchers or stakeholder managers. In this particular research, interviews with key decision-making stakeholders were used to gain enough knowledge about each attribute to give a ranking for the stakeholders in that attribute. Other methods of ranking could be possible; for example, self-ranking in comparison to other stakeholders, ranking based on survey results or a stakeholders' workshop.

The interviews were conducted between March and October 2015 to determine the influence of various stakeholders on the energy efficiency outcomes. "Controllers/ decision-maker stakeholders" (owner, design and main contractor) were interviewed due to their direct involvement during the design and construction stages in making major decisions that could affect the energy efficiency outcomes, their closeness to the work onsite, and their high connectivity and accessibility to/possession of information when compared to other stakeholders (Zedan and Miller 2015). The SIPs manufacturer supplies 140 mm steel-skinned structural insulated panels with an R-value of 3.59, which (if constructed correctly) could enhance the energy efficiency of the house. The national sales manager of the product was interviewed because this product is new to the culture of practice in the housing sector in Australia and it was considered important to understand how the manufacturer could influence the decisions of other stakeholders (through training, publicity, etc.) and contribute to the implementation of energy efficiency. The interview with the SIPs manufacturer/supplier revealed that (1) they are interested in their product's reputation as a facilitator of energy efficiency of housing; (2) they provide training and guidance to stakeholders only when requested but without getting involved in the design or construction; and (3) they do not supervise how their product is used (i.e. they do not control if the product is utilized in a manner that could maximize the overall energy efficiency of the house). The interviews were recorded and transcribed then analysed using Nvivo.

Results and discussion

The results of each of the four stages are discussed separately and the rankings of certain stakeholders' attributes are explained as an example of how the whole process has been applied to explain degrees of influence in these specific case studies. The heterogeneity of housing markets means that these specific results are not generalizable and cannot be statistically analysed. However, the results show that the process can be successfully applied to enhance understanding of influences on energy efficiency outcomes.

Stage one results

Figure 4 compares the eigenvector centrality of stakeholders of energy efficiency in the six case studies. The SIPs suppliers' connectivity variation between case studies is a good example of how the eigenvector centrality evaluates stakeholders' importance based on the impact of connections to certain stakeholders in the network. Figure 4 shows that the SIPs supplier has the highest connectivity with stakeholders of houses 2 and 3 due to their direct connection with more than one important stakeholder (the contractors and the owners of these houses). In house 4, the SIPs supplier is also connected to the contractor and owner; however, they have a lower eigenvector value since the contractor centrality in that case study is low. House 1 shows the lowest eigenvector centrality value for the SIPs supplier since they are only connected to the network through one stakeholder (the owner).

Another example is House 6, which shows strong fluctuations of the eigenvector value among stakeholders. This is due to the owner/contractor's attempts to enhance communication among many stakeholders prior to the design phase, which resulted in granting some stakeholders (who have low connectivity in other case studies) connections with influential stakeholders.

In general, the graph shows that the highest centrality is among the owner, designer and contractor (controllers/decision-makers), followed by the regulator, certifier and engineer (legal authorities), then the suppliers and executors. The eigenvector value of each stakeholder is used

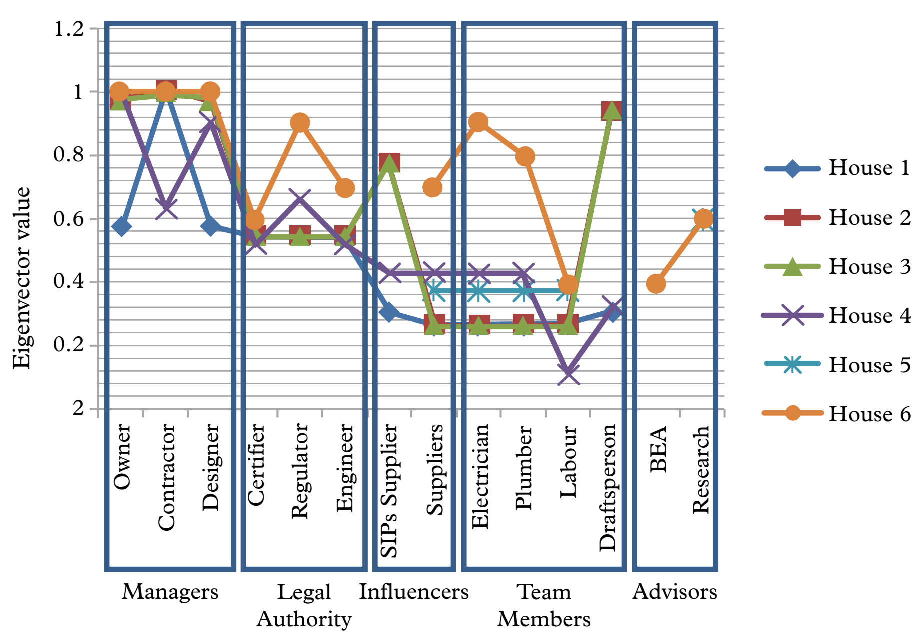

Figure 4. Eigenvector value of the case studies' stakeholders.

to represent the political power and is integrated in an equation with the other sources of power to produce the overall power of each stakeholder.

Stage two results

Figure 5 shows that the regulator and certifier in all case studies are evaluated as "high knowledge" and "high authority" since the regulation and certification processes rely on an integrated knowledge of energy efficiency principles and both the certifier and regulator have legal authority to impose certain energy efficiency measures on the rest of the stakeholders. Their connectivity power is evaluated as medium (except in house 6 which had an enhanced communication process) since they mostly communicate only with one stakeholder (usually the contractor).

The suppliers and executors' power is generally low except in house 5 where the connectivity is high since they are all connected to the most central stakeholder (the owner). The model of house 5 might represent a way to enhance information sharing through having one central stakeholder who acts as a "hub", has all the information, and is connected to all the stakeholders. The "central information hub" or "building passport concept" is proposed in recent literature to serve as a platform where all the building information can be stored and extracted when needed to enhance interchanging communication and making informed decisions (Lützkendorf and Speer 2005, Zedan and Miller 2015, Miller and Lutzkendorf 2016).

Figure 5(a)–(f) collectively show the variations in power rankings of each case study's stakeholders and the variations between case studies. The owners/designers with

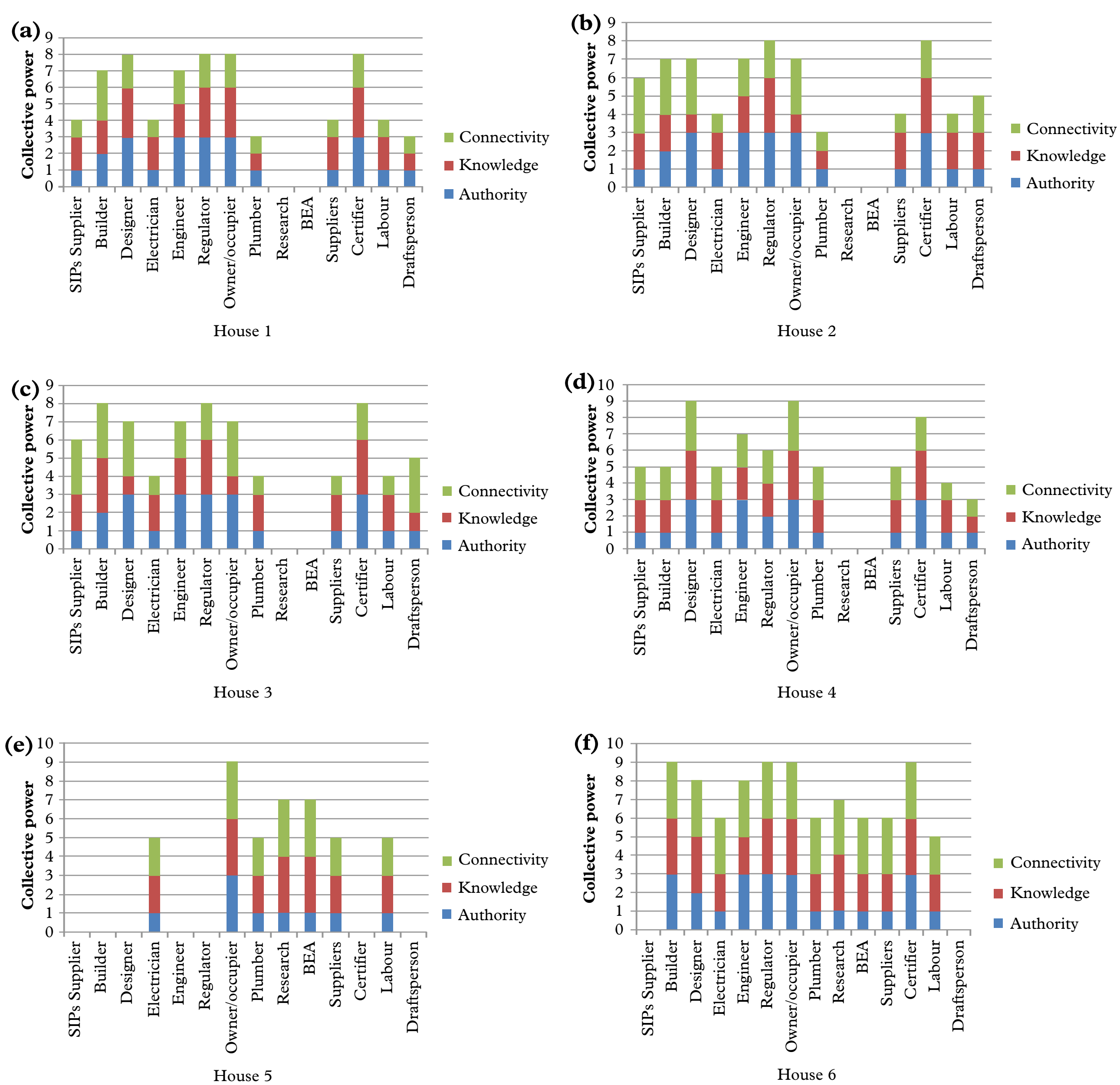

Figure 5. Stakeholders' power rankings for houses 1–6.

the maximum level of power are those of houses 4, 5 and 6 (Figure 5(d)–(f)), due to their expertise in energy efficiency principles and high connectivity because of their involvement in the construction industry and authority from their ownership. Contractors of the case studies have lower or equal power to the owner/designer except for house 3's contractor (Figure 5(c)). In this case, the contractor has higher power than the owner due to his knowledge and expertise in building energy efficient houses and the owner's willingness to entrust him with this power. The power score resulted from Equation (2) gives each stakeholder a rank for power that is used as one of the three main attributes to quantify influence as explained in the next section.

Stage three's results

Figure 6(a)–(f) shows the stakeholders' main attributes rankings. From the graphs, it is evident that the "decision-maker" stakeholders (owner, designer, and contractor) have the highest "power" and "proximity". However, it is important to note that the designers' influence in houses 1 to 5 is high, since the owner-occupiers designed the houses (either professionally or with the help of a draftsperson) as explained in Table 7. Stakeholders who have the multiple roles of owner, occupant, and designer have higher stakes of energy efficiency outcomes when compared to other designers who are not going to actually use or pay for the house. The contractor of house 4 is an exception in terms of high power and proximity, since he

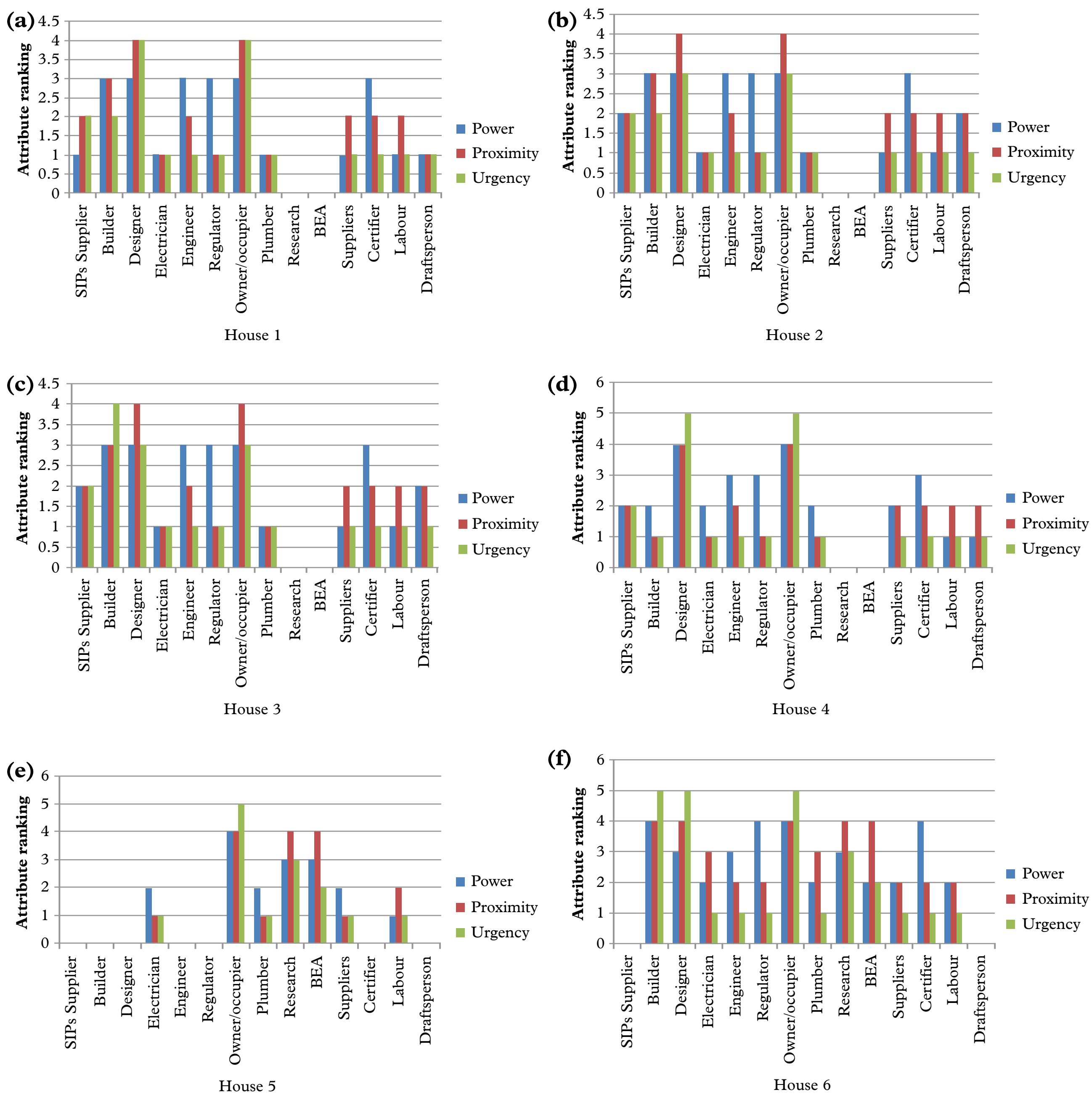

Figure 6. Stakeholders main attributes' rankings for houses 1–6.

was not fully in charge of the construction decisions and worked under the owner's supervision.

The owners and designers of all the case studies have the highest proximity since they were in charge of decisions that had major impacts on energy efficiency, such as setting the budget, developing the design either personally or in very close cooperation with a designer, and choosing the building materials. Researchers and building energy assessors have high proximity in houses 5 and 6 due to their contribution to the decision-making by providing information that helped owners/designers make design decisions that enhance energy efficiency. The "legal authority" stakeholders have a medium proximity since they indirectly influence the upwards stakeholders' decisions through setting and ensuring compliance with the regulations. The downwards stakeholders have low proximity because their roles are mainly to follow the instructions of the upwards stakeholders (although in some cases the executor stakeholders can influence the upwards stakeholders' decisions due to the lack of knowhow. This situation, however, did not occur in any of the studied houses). House 6 has the largest number of stakeholders with high proximity because of their early involvement in the decision-making process prior to the design phase. This was a deliberate strategy of the owner/designer in an attempt to maximize energy efficiency outcomes for this particular climate whilst minimizing any potential increase in construction costs.

The degree of interest (value and action) in energy efficiency of the owners of houses 1, 4, 5 and 6 is higher than the other houses, since energy efficiency was their main goal. The owners of these four houses were also prepared to spend extra money, time or effort researching materials properties or developing the design to reach the optimum level of energy efficiency. The value to the contractor varies from one case study to the other. For instance, the contractor of house 6 has the highest interest since energy efficiency is important for his business (building an energy efficient display home) and to his quality of life (he will be the occupant of the house). The contractor of house 3 has high value since he considers developing his skills in building energy efficient houses a priority. The SIPs supplier has higher value than other suppliers, reflecting the role this business sees for this new product in the energy efficiency sector.

Table 9. Stakeholders' time factors.

	House 1	House 2	House 3	House 4	House 5	House 6
SIPs Supplier	1	1	1	1		
Contractor	1	1	1	0.9		1
Designer	1	1	1	1		1
Electrician	0.9	0.9	0.9	0.9	0.5	1
Engineer	1	1	1	1		1
Regulator	1	1	1	1		1
Owner/occupier	1	1	1	1	0.5	1
Plumber	0.9	0.9	0.9	0.9	0.5	1
Research					0.5	1
BEA					0.5	1
Suppliers	0.9	0.9	0.9	0.9	0.5	1
Certifier	1	1	1	1		1
Labour	0.9	0.9	0.9	0.9	0.5	1
Draftsperson	1	1	1	1		

Stage four results

The influence of each stakeholder was calculated based on the sum of the ranking discussed in stage 4 of the methodology and multiplying it by the time factor (using Equation 3b). In this study, it was assumed for all case studies that the degree of flexibility to changes between the design and construction stages was high and became much lower during the use stage. This is due to the assumption of the reluctance of most owners/occupiers to make major changes to the house once the contractual agreement with the contractor is signed. Therefore, for these case studies the time factor (as shown for each stakeholder in Table 9) ranges between 0.5 (for stakeholders who joined the project in the use stage), 0.9 (for stakeholders who joined in the construction stage), and 1 (for stakeholders who joined in the design stage).

A comparison of the influence of stakeholders (Figure 7) shows that, for each case study, managers have the highest influence, followed by the "advisors" (research and simulation) then the legal authority (engineer, regulator, and certifier) and the influencers (suppliers). The lowest influence is for the downwards stakeholders (labor, electrician, plumber, etc.). The draftsperson influence varies depending on the level of their involvement in design development. The parallel design and construction processes followed in house 6 increased the time factor of all the stakeholders (Table 9) since they were all involved during the design stage. In contrast to the typical situation where stakeholders such as executors only join projects in the construction stage, the early involvement of these stakeholders in this increased their potential influence on energy efficiency.

This could mean that a "design and build" procurement approach could have better influence on energy efficiency than a traditional procurement process which separates design from construction. House 6 also shows high influence by stakeholders potentially due to the enhanced communication between the stakeholders at an early stage of the house's procurement, increasing their level of political power, proximity, and time factor and consequently their level of influence.

All the stakeholders of house 5 (the retrofit case study) have a time factor of 0.5, due to their involvement in the use stage. This late involvement resulted in significantly lowering the collective influence since major design

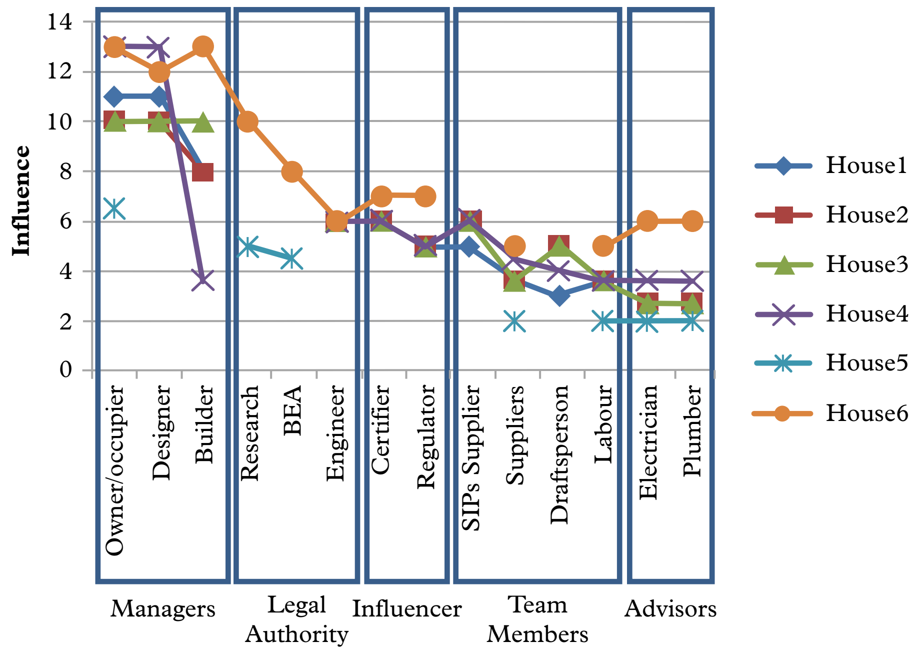

Figure 7. Comparison of stakeholders' influence.

decisions impacting on energy efficiency had already been made (e.g. building orientation and construction materials). The owner made only relatively minor design changes (e.g. adding insulation, removing some internal walls, adding an equatorial facing glass door to an external wall).

Research limitations

One of the limitations of this methodology that needs further development is the use of simple average instead of weighted average for measuring the power and interests' attributes. Bourne and Walker's approach offers the ability to assign weights from 1 to 9 for the action and value attributes depending on their importance to a certain project (Bourne and Walker 2006). Olander (2007) suggested that attributes are of almost equal importance, except power, which could be of slightly higher importance (Olander 2007). However, these approaches agreed that there is no specific weighting that fits all projects, and that attributes' importance is changeable from one project to the other (Bourne and Walker 2006, Olander 2007).

Therefore, further development of the four-step methodology could focus on the weightings of each attribute based on their relevance or contribution to influencing energy efficiency, so that a specific weighting could be set for managing energy efficiency. This could be done through quantitative surveys of housing industry stakeholders to identify the importance of the attributes in relation to each other.

Another limitation is the qualitative data collection method (interviews) used for ranking the stakeholders' attributes. This method of data collection may render it difficult to replicate by other researchers. Further development of survey questions to measure the possession of the attributes (e.g. following latent variables and psychometrics measuring approaches), could result in a methodology with the potential to be replicated.

A third limitation of the methodology is that it only considers one dimension of time (e.g. the stage at which a stakeholder is involved) but does not address the duration of stakeholder involvement. This topic is rarely addressed in literature. The notion of the duration involvement itself could transcend the interpretation of being physically a part of the project's team during a certain phase(s). Instead, it could be regarded as the contractual agreement that ensures the sharing of risks and rewards and keeps stakeholders liable for their actions even when their role during the procurement is finished (Aapaoja *et al*. 2013).

This method of project delivery and types of contractual agreements between stakeholders could impact the attributes of influence differently. For instance, responsibility agreements could increase stakeholders' interests in the quality of projects' outcomes. Contracts assigning the scope of work for stakeholders could affect their proximity to the decision-making process. Therefore, further research is needed to understand the magnitude and direction of the impact of duration of involvement by stakeholders.

The methodology presented in this paper has focused only on the time of involvement effect on the collective influence of stakeholders (the influence resulted from power, proximity and interest collectively). It addresses the potential to utilize that collective influence from combining all attributes. Further research could address the effect of different types of project delivery agreements/processes on the change of different attributes with time. Further research could also focus on creating a more refined scale that is built on significant correlation between the time of involvement and energy efficiency outcomes. Such a scale could be developed based on analysis of stakeholders' perception about each task's impact on the possibility of implementing changes that could enhance or decrease energy efficiency outcomes.

Conclusion

Enhancing energy efficiency of housing requires better management of housing stakeholders during the procurement stages and a thorough understanding of each stakeholder's influence on energy efficiency outcomes. Such understanding can assist in the development of informed policies and management strategies that provide a balance between stakeholders' interests and the implementation of energy efficiency, and target certain attributes of stakeholders based on their role in enhancing energy efficiency.

Building on previous research on the analysis of stakeholder influence, a four-stage methodology that aims to measure the degree of influence on energy efficiency was proposed. This methodology takes into consideration and reinterprets the attributes that influence the implementation of energy efficiency, and combines them into an equation, in a manner that could reflect stakeholders' influence.

The multiple attributes equation helps to identify the reasons behind the negative/positive influence of stakeholders on energy efficiency, whether these reasons are related to power, interest, time, etc. This could enable project managers and policy-makers to develop plans that target specific attributes of certain stakeholders for better energy efficiency outcomes.

This methodology was applied on case studies for reflection and sense making, showing the practical application of the methodology. The methodology's limitations, however, indicate that further research and development is needed to enhance the replicability of the method and determine if results can be statistically quantified and analysed. Further development and statistical analysis of this methodology could identify the correlation between certain patterns of stakeholders' relationships and attributes rankings, and the actual energy performance of housing. This correlation (if found) could help policy-makers and researchers orchestrate housing stakeholders for better energy efficiency outcomes.

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