Low Carbon Readiness Index: A short measure to predict private low carbon behaviour

RUNNING HEAD: Low Carbon Readiness Index

Abstract

This paper presents a theoretical argument that low carbon strivings – personal goals to reduce carbon footprint in the household – can predict a wide range of diverse behaviours to reduce greenhouse gas emissions, and reports four studies to validate Low Carbon Readiness Index (LCRI), a short, three-item measure of low carbon strivings. It is a simple and easy-to-use indicator of the general public's readiness to transition to a fully low carbon lifestyle. LCRI is associated with validated measures predicting environmentally significant reported behaviour (Study 1), multiple low carbon behavioural clusters (Study 2 & 3), and predicts reduction in actual energy use, arguably an aggregate measure of actual low carbon behaviours (Study 4). LCRI can be used to develop low carbon policies and monitor their implementation.

Key words: Environmental behaviour; low carbon; behavioural cluster; goal

1. Introduction

Human-caused greenhouse gas (GHG) emissions are a major driver of climate change (IPCC, 2014) and the private sphere currently makes up about a third of total emissions (Wright, Osman, & Ashworth, 2009). For private citizens, the immediate means to reduce GHG emissions is to modify their behaviours in the domain of household and personal travel (DEFRA., 2008; Gardner & Stern, 2008; Pears, 2011). Reductions can be achieved by using infrastructure that is energy efficient (e.g. efficient appliances, insulation) and that makes renewable energy available (e.g. solar panels), and by adopting routines that conserve energy (e.g. temperature curtailment) and minimise waste (e.g. composting). While it may be difficult to implement all possible measures to reduce GHG emissions, most people could make at least some changes. However, although a recent survey found that climate change is globally seen as a major threat (Pew Research Center, 2017), transition to low carbon living in the private sphere remains slow.

In order to aid policy making and implementation that promotes the reduction of GHG emissions in the private sphere, we present a short and easy-to-use three-item measure called the Low Carbon Readiness Index (LCRI). Note that the name of the measure references carbon for ease of communication as discernible from the standard practice of converting GHGs to carbon equivalents. Nevertheless, the items for this measure are phrased in terms of "greenhouse gasses" to capture other types of GHGs (e.g., methane) as well, so as to be relevant for a broader set of household behaviours including waste reduction (i.e., those aimed at reducing methane). The LCRI is designed to measure personal motivation to transition to low carbon living, and to predict a wide range of diverse behaviours that can reduce household GHG emissions. We report four studies to validate the claim and close the paper by discussing how the LCRI can be used to support efforts to promote low carbon living.

1.1 Predicting transition to low carbon lifestyle

Although a number of approaches have been used to predict environmental behaviour (e.g., Gifford, 2014, for a review), the Reasoned Action Approach (RAA: Ajzen, 1991; Fishbein & Ajzen, 1975; Fishbein & Ajzen, 2010) has been one of the most widely used. Many of its applications have focused on specific environmental behaviours, such as composting (Mannetti, Pierro, & Livi, 2004; Taylor & Todd, 1995), use of energy-saving light bulbs, unbleached paper, water and meat consumption (Harland, Staats, & Wilke, 1999), and mode of travel (Bamberg & Schmidt, 2003; Harland et al., 1999; Heath & Gifford, 2002; Verplanken, Aarts, Knippenberg, & Moonen, 1998), although there has been an effort to conceptualize a generalized use of the Reasoned Action Approach (Kaiser & Gutscher, 2003). This focus on specific behaviour is partly due to the RAA's *principle of compatibility*, which suggests that predictors of a behaviour must be measured at the level of specificity compatible with the behaviour. For instance, to predict a specific behaviour such as "installing solar panels for my house next month", its predictor must also be specified in terms of its four elements, action (installing), target (solar panels), context (my house), and time (next month).

Nevertheless, the same methodological principle suggests that a general category of behaviours can be predicted by predictors if they have compatible levels of specificity (Ajzen & Fishbein, 1977; Fishbein & Ajzen, 2010). Thus, "intentions to perform a range of behaviours that can potentially reduce carbon emissions in the household" should be able to predict a diverse array of low carbon behaviours. We suggest that such generalized intentions are conceptually akin to personal goals (Carver, 2015). Indeed, Kashima, Paladino, and Margetts (2014) showed that *environmental strivings*, personal goals to improve the natural environment – a construct based on Emmons's (1986) personal strivings – predicted a wide range of pro-environmental

behaviours including green shopping, green talk, driving less, as well as willingness to pay a "Sustainability Fee" at the university (Margetts & Kashima, 2016). Analogously, we suggest that personal goals to reduce carbon emissions may be conceptualized as *low carbon strivings*, and the Low Carbon Readiness Index (LCRI), a measure of this construct developed from the environmental strivings measure, should be able to predict a wide range of low carbon behaviour within the household.

1.2 Why should low carbon strivings predict low carbon behaviours?

Adoption of low carbon behaviours (e.g., turning off the light) typically requires an abandonment of pre-existing routinized high carbon behaviours (i.e., keeping the light on), which have been repeatedly practised in people's everyday activities within their household. That these pre-existing behaviours are difficult to change can be understood from at least two perspectives (Kurz, Gardner, Verplanken, & Abraham, 2014). First, psychologically speaking, repeated acts can form a habit (e.g., Verplanken, 2005; Wood & Neal, 2007), so that when a contextual cue is present, the act is likely performed unreflectively (Neal, Wood, & Quinn, 2006). Past behaviour, therefore, is the dominant predictor of future behaviour in the same context (e.g. Danner, Aarts, & Vries, 2008; Knussen, Yule, MacKenzie, & Wells, 2004) and Ouellette and Wood's (1998) meta-analysis provides evidence. Second, the pre-existing behaviours are embedded in socio-cultural context. From a sociological perspective (e.g., Shove, Pantzar, & Watson, 2012), they constitute *practices* – a set of routinized behaviours that accompany (i) the capacity to perform physical actions or procedures (competence), (ii) things that are used to carry out the behaviour (material), and (iii) knowledge, emotion and motivation (meaning). Cultural understandings shared amongst people maintain a "community of practice" that structures multiple individuals' behaviours (Shove, 2012; Shove, Pantzar, & Watson, 2012) and their relationships (Hargreaves,

2011). Any change to a system of practices tends to disrupt the status quo, and therefore tends to be resisted.

However, dual process perspectives (e.g., Borland, 2013; Kahneman, 2011; Sloman, 1996; Triandis, 1977; see Evans, 2008, for a recent review) suggest that these habitual practices can be cognitively regulated under some circumstances. To use Kahneman's (2011) well known nomenclature, *type 1 processes* are non-volitional mental processes (including habit) that are reactive to the immediate environment (Fazio, 1990; Kahneman, 2011). In contrast, *type 2 processes* are deliberative and reflective. They can implicate higher order goals and aspirations that may be incongruent with the type 1 processes, and are effortful, difficult to sustain, and frequently unsuccessful (see Borland, 2013). To change pre-existing high carbon behaviours to low carbon alternatives requires an override of easy type 1 processes by more difficult type 2 processes. Nonetheless, as Wood, Labrecque, Lin, and Rünger (2014; also see Triandis, 1977) noted, the mental processes governing habit performance will typically occur in tandem with other, more intentional and goal-oriented, processes. This creates a possibility for type 2-guided behaviour changes to occur across different contexts over a period of time. Thus, *low carbon strivings may exert effects when there are opportunities for type 2 processes to regulate behaviour, thus cumulatively leading to a low carbon lifestyle over time*.

There are at least two classes of factors that may moderate a general tendency to engage in low carbon behaviour this way. One is the *perceived effectiveness* of a given behaviour in helping achieve the personal goal to reduce GHG emissions. Even if people are highly motivated to attain the personal goal of reducing GHG emissions, if they wrongly believe that a given behaviour is ineffective in doing so, they may not engage in type 2-guided self-regulation of the behaviour (Kashima et al., 2014). There is also considerable diversity in the way people perceive

the effectiveness of different behaviours in reducing energy consumption (Attari, DeKay, Davidson, & De Bruin, 2010). The other class of factors is the extent to which people have actual control over their behaviour (e.g. Fishbein & Ajzen, 2010); we may call this *actual difficulty*. As sociological perspectives highlight, behaviour change requires competences and materials (Shove et al., 2012). If people do not have control over a GHG reduction behaviour due to their lack of skills, resources, or opportunities (e.g. renters cannot install solar panels), or if the behaviour is actually very difficult (rather than perceived to be difficult) to perform, people may not be able to carry it out even if they have strong personal goals to reduce GHGs and they know its effectiveness. Variation introduced by these factors reduces the correspondence between general striving for GHG reductions and low carbon behaviour.

1.3 What type of low carbon behaviours can low carbon strivings predict?

The foregoing discussion provides a theoretical justification for the methodological principle of compatibility (e.g., Fishbein & Ajzen, 2010). A measure of a construct with a low level of specificity such as low carbon strivings can predict, not single-act criterion with a specified act, target, context, and time, but multiple-act criteria which capture a wide range of diverse behaviours with different configurations of act, target, context, and time. Nonetheless, creating a meaningful measure of diverse low carbon behaviours is difficult because low carbon behaviours in the household are highly heterogeneous, including daily curtailment behaviours (e.g. regulating heater use), occasional compensatory behaviours (e.g. carbon offsetting), and long-term investment in efficient infrastructure (e.g. energy efficient fridge).

Nonetheless, we can rely on behavioural clustering to construct meaningful behavioural criteria. Behavioural clustering is a phenomenon in which diverse behaviours tend to co-occur in a population, such that if a person engages in one behaviour in a cluster, he or she is also likely

to engage in other behaviours in the cluster. Behaviour clusters are empirically identified using methods such as factor analysis, cluster analysis, and latent class analysis, and have been documented in environmental psychology. For example, in Norway, Bratt (1999) identified three behavioural clusters: recycling and information-based behaviours, transport behaviour, and residential energy consumption. In the UK, Gilg, Barr, and Ford (2005) found three clusters: shopping, composting, and reuse; domestic water and energy conservation; and recycling. In Germany, Mills and Schleich (2010) found that the likelihood of purchasing energy efficient household appliances and whitegoods was higher in homes that already had one or more energy efficient appliances. This effect was strong and consistent across appliance type, implying the existence of a "household appliance installation" cluster.

There is also evidence of higher order associations between different behavioural clusters. For example, Berger (1997) identified six clusters of pro-environmental household reported behaviour using principal components analysis in Canada: recycling, transportation, energy use, lawn chemicals, water use, and "other" consumer behaviours. She also found that the recycling cluster was associated with substantially increased levels of many other pro-environmental behaviours, including those that were not related to waste management. For example, she found that nearly twice as many recyclers used a programmable thermostat, composted, and used their own shopping bags (Thøgersen & Ölander, 2006). Behaviour clustering is conceptually related to spillover effects in which the performance of one environmental behaviour increases the likelihood of performing another (e.g., Lanzini & Thøgersen, 2014; Lauren, Fielding, Smith, & Louis, 2016; Margetts & Kashima, 2017; Thøgersen, 1999; Thøgersen & Noblet, 2012; Thøgersen & Ölander, 2003).

Thus, behavioural clusters identify naturally co-occurring actions across target, context, and time. Measures that capture a person's engagement with behavioural clusters amount to measuring broad and heterogeneous behaviours. We expect, therefore, that level of engagement with a low carbon behaviour cluster will depend on the perceived effectiveness and actual control that people have. However, we also expect that people who have a strong personal goal to reduce GHG emissions will be more likely to engage in the comprising behaviours of the cluster. We therefore hypothesise that low carbon strivings should be able to predict the extent to which people engage with low carbon behavioural clusters. This line of reasoning is consistent with Thøgersen and Ölander's (2003) finding that environmental values and environmental concern predicted participation in clusters focussed on recycling, food purchasing and transport. Similarly, when Truelove, Carrico, Weber, Raimi, and Vandenbergh (2014, p. 132) reviewed the literature on spillover from performing one low carbon behaviour to performing others within a cluster they concluded that this process occurs when there is "[s]ocial and internal pressure to live up to an assumed role". We suggest that low carbon strivings can represent such higher order concerns, values, and standards.

1.4 Validating the LCRI

Here, we present four studies that support the construct validity of the Low Carbon Readiness Index (LCRI) as an indicator of low carbon strivings, namely, personal goals to reduce carbon emissions in the household. First, to show convergent validity, we test whether LCRI is associated with other measures of pro-environmental orientations. Second, to show construct validity, we conduct two studies to test the coherence of the LCRI measure and whether LCRI is associated with self-reported behaviours and greater intentions to perform behaviours in low

carbon behavioural clusters. Finally, we test whether LCRI can predict actual energy consumption, arguably an aggregate measure of actual household low carbon behaviours.

2. Study 1

We constructed LCRI and investigated its relationships with three measures of pro-environmental orientations: New Ecological Paradigm (Dunlap, Van Liere, Mertig, & Jones, 2000) as a benchmark of generalised environmental attitudes, environmental identity (Whitmarsh & O'Neill, 2010), and environmental striving (Kashima et al., 2014). We also included a measure of climate change beliefs because the most salient reason for reducing carbon emissions is likely to be climate change mitigation (Hulme, 2009).

2.1 Method

One-hundred-and-two Australians (51 female) aged 21 to 80 years (M_{age}=45.18, SD_{age}=13.34) were recruited by Qualtrics Panels and completed a 20-minute survey. (For more detail on recruitment and sample size see Supplementary materials).

2.1.1 Low Carbon Readiness Index (LCRI)

LCRI items were developed by modifying Kashima et al.'s (2014) environmental strivings measure: (1) I work hard to reduce my greenhouse gas emissions whenever possible; (2) I feel very good when I am successful in reducing my greenhouse gases; (3) I would feel very bad if I did not reduce my greenhouse gas emissions (Strongly disagree; Disagree; Neither agree nor disagree; Agree; Strongly agree).

2.1.2 Comparison measures for convergent validity

We used three measures to check convergence with LCRI: Dunlap et al.'s (2000) New Ecological Paradigm (Cronbach's α =.91; M=3.65, SD=.66), Whitmarsh and O'Neill's (2010)

environmental identity (Cronbach's α =.69; M=3.84, SD=.68), and Kashima et al.'s environmental strivings (Cronbach's α =.87; M=3.52, SD=.76).

Leviston, Walker, and Morwinski's (2012) item was used to gauge climate change beliefs (see Supplementary materials) and an uneven distribution of responses (63.73% endorsed human-caused climate change), meant this measure was dichotomized: belief in anthropogenic climate change was coded as 1, and all others as 0.

2.2 Results

2.2.1 Constructing LCRI

We averaged the three items to compute LCRI (Cronbach's α =.90; M=3.55, SD=.88; see Supplementary analyses for results of principal components analyses across studies).

2.2.2 LCRI association with comparison measures

LCRI significantly correlated with each comparison measure (NEP, Environmental Identity and Striving, and belief in human-caused climate change; see Table 1).

Table 1. LCRI association with comparison measures in studies 1 and 2

		LCRI	NEP	Belief in human-caused climate change	Environ-mental identity
Study 1	NEP	.48***			
	Belief in human-caused climate change	.39***	.50***		
	Environmental identity	.55***	.61***	.45***	
	Environmental striving	.65***	.50***	.31**	.61**
Study 2	NEP	.52***			
	Belief in human-caused climate change	.42***	.45***		
	CC knowledge	.38***	.37***	.36***	
	Social desirability	.10	.07	-.09	

***p <.001, **p<.01.

3. Study 2

To further demonstrate LCRI's validity, its correlations with low carbon behavioural clusters and related intentions were examined. Reported behaviours included the installation of infrastructure and the performance of routine actions, initially selected from the description of a 'green' Australian household provided by Pears (2011) and the CSIRO Home Energy Saving Handbook (Wright et al., 2009). A pilot test (N=50) confirmed that a community sample of Australians also listed the chosen behaviours as examples of low carbon behaviour.

We also compared LCRI's ability to predict clusters of reported behaviour and intentions relative to a standard measure (i.e., NEP). As in Study 1, we examined whether belief in human-caused climate change and climate change knowledge were associated with LCRI. Finally, to account for social desirability, we included a modified social desirability scale based on Reynolds (1982).

3.1 Method

3.1.1 Participants & procedure

Two hundred and twenty-seven Australians (109 female; 59.5% homeowners) aged 21 to 81 years (M_{age}=51.12; SD_{age}= 4.38) were recruited by Qualtrics Panels and completed an online survey approximately 30 minutes in length. (For more detail on recruitment, sample size and sample characteristics see Supplementary materials).

3.1.2 LCRI

LCRI (Cronbach's α =.87; M=4.74, SD=1.15) was the same as in Study 1 but used a 7-point scale (Strongly disagree; Disagree; Somewhat disagree; Neither agree nor disagree; Somewhat agree; Agree; Strongly agree).

3.1.3 Current infrastructure and routine low carbon behaviour

Participants were asked, "Do you have this feature in the place you live at the moment?" for the infrastructure items listed in Table 2. The distribution of raw responses is provided in the Supplementary materials. For analysis, dichotomous measures were made where all "Yes" responses were collapsed into a single category, coded 1, and the remainders were coded 0. Preliminary analysis indicated this simplification did not obfuscate a pattern of differences for the different yes responses. While the people who acquired low carbon infrastructure by moving into a residence did not purchase the infrastructure directly, they may have chosen their residence on the basis of its low carbon infrastructure.

Participants were then asked, "How often have you typically done these behaviours in the past?" for the routine behaviour items listed in Table 2.

3.1.4 Intentions

Participants were first asked about their intentions to buy or install the pieces of infrastructure they reported not having. The questions were phrased "In the next twelve months, I intend to buy and/or install…" Participants were then asked about their intentions to engage in the routine behaviours they had been previously asked about. The questions were phrased "In the next month, I intend to…". In both cases, responses were recorded on a 7-point Likert scale (Strongly disagree; Disagree; Somewhat disagree; Neither agree nor disagree; Somewhat agree; Agree; Strongly agree).

3.2 Constructing behavioural clusters of low carbon behaviours

3.2.1 Summary measures for clustered infrastructure

To identify clusters of reported infrastructure installation behaviours, dichotomous measures were submitted to hierarchical clustering using Ward's method and Squared Euclidian

Distances. As shown in the dendrogram in Figure 1, two clusters were identified: solar (solar panels, solar hot water) and appliances (washing machine, dishwasher, fridge and small appliances). Summary measures were calculated for these infrastructure clusters by summing the comprising dichotomous measures. Corresponding summary measures for cluster intentions were also calculated by averaging intention responses for each identified cluster (appliances Cronbach's α =.81; solar Cronbach's α =.84). Temperature system did not cluster closely with the other measures; it was used as a single item for past practice and intention. Similarly, while efficient car clustered with solar technology, this relationship was not supported by inter-item correlations, so efficient car was also examined as a single item.

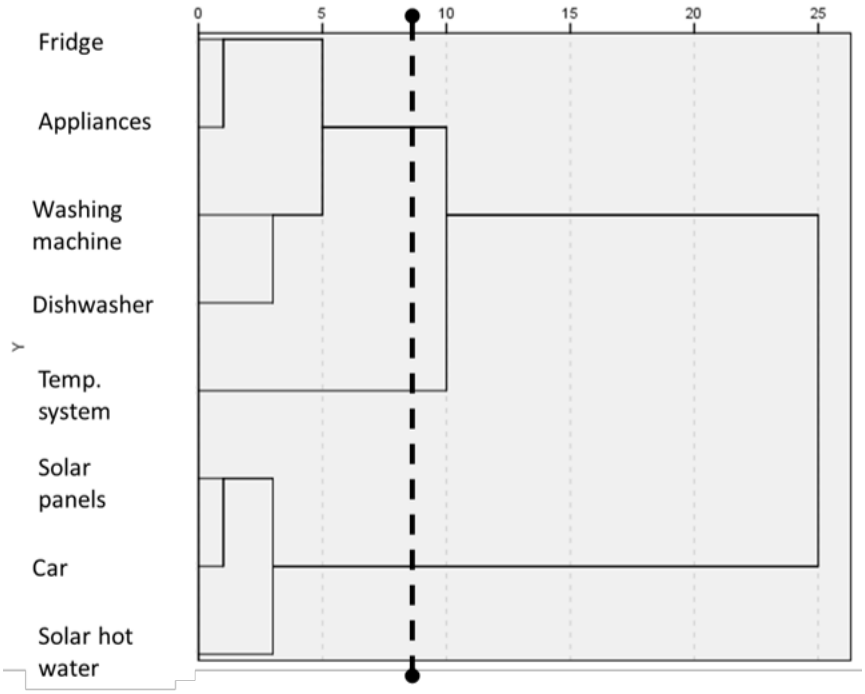


Figure. 1. Study 2: Hierarchical clustering of infrastructure with Ward's method

3.2.2 Behavioural clusters for routine behaviour

A principal component analysis with oblimin rotation was conducted using the past routine reported behaviour items. Two components were extracted (Kaiser-Meyer-Olkin Measure =.75, Bartlett's Test of Sphericity $\chi^2(28) = 458.71$, $p < .001$). The first factor comprised the temperature curtailment practices (eigenvalue = 2.66, 33.24% variance explained), while the second comprised green payments and travel practices (eigenvalue = 2.00, 24.95% variance explained). Summary measures were calculated for these clusters by averaging the past reported behaviour measures. Corresponding summary measures were computed by averaging intentions for each identified cluster (temperature curtailment Cronbach's $\alpha = .70$; green payments and travel Cronbach's $\alpha = .67$).

Table 2. Survey items used to construct behavioural cluster measures in Studies 2 and 3

	Cluster name	Comprising survey item	Present S2	Present S3	Response options S2	Response options S3
Infrastructure	Solar	· Photovoltaic solar panels	x	x	· I don't know · No · Yes, it was there when I moved in · Yes, I installed it	· I don't know · No · Yes
		· High performance solar hot water system	x	x		
	Temp-erature system	· Reverse cycle heating/cooling system or energy efficient systems with 5-6-star energy ratings for all temperature control devices	x			
		· Reverse cycle heating/cooling system		x		
		· Heater or with a 5-6 star energy rating[a]		x		
		· Cooler a 5-6 star energy rating[a]		x		
	Appliances	· Efficient washing machine (5-6 star energy rating)	x	x		
		· Efficient fridge (5-6 star energy rating)	x	x		
		· High proportion of your small appliances are energy efficient (e.g., your toaster, kettle and blender are 5-6 star energy rated)	x			
		· Efficient dishwasher (5-6 star energy rating)	x		· I don't know · No · Yes, it was there when I moved in · Yes, I installed it · No, I do not have a dishwasher	
	Car	· Energy-efficient car[1]	x	x	· I don't know · No · Yes, some are energy efficient · Yes, all are energy efficient · No, I do not have a car	
Routine behaviour	Temp-erature curtailment	· Only heated/cooled the rooms of your home that were used	x		· Never · Rarely · Sometimes · Often · Very often · Always	
		· Used curtains, awnings, shutters, blinds and/or vegetation for shade	x			
		· Worn seasonal clothing to keep warm/cool	x			
		· Opened doors and windows to cool home when the weather is going to get hot later	x			
		· Minimize how much heating or cooling is used		x		
	Green travel & payments	· Used the GreenPower option (i.e. paid a premium to support contribution of renewable energy to the grid) for some or all of the electricity bill[b]	x	x		
		· Avoided driving a car for most travel (e.g. public transport, small motorbike, bike or walk)	x	x		
		· Carbon off-set air trips[b]	x	x		
		· When driving, carpooled with others	x			

[a]Only asked if response to 'Reverse cycle heating/cooling system' question was not 'Yes'.

[b]Additional option for GreenPower was 'I don't use energy from the grid' and for Carbon off-set was 'I don't use air travel'. These responses were not analysed.

[1] 'Energy-efficient' for cars in the Australian context includes small fuel-efficient cars and those of electric or hybrid design (Wright, Osman, & Ashworth, 2009). Multiple 'Yes' response options checked how commonly people with energy-efficient cars (15.9%) had a second car that was not energy-efficient (10.6%).

3.3 Comparison measures

We included NEP (Cronbach's α =.89, M=4.84, SD=.90) and the climate change belief measure as in Study 1. In addition, climate change knowledge was measured using a Climate Change Quiz, developed by Berry and Raupach (2014; e.g. Greenhouse gases strongly influence climate) in collaboration with the Australian Academy of Science. Finally, social desirability was measured using a scale comprising six statements from Reynolds (1982; e.g. I am always courteous even to people who are disagreeable, Cronbach's α =.70). For more detail see Supplementary materials.

3.4 Results

3.4.1 LCRI association with comparison measures

The LCRI measure showed significant positive correlations with the comparison measures (NEP, belief in human-caused climate change, and climate change knowledge; Table 1). None of the measures were associated with social desirability.

3.4.2 Infrastructure

A series of analyses were conducted to examine whether LCRI and comparison measures could predict past acquisition of low carbon infrastructure clusters: multinomial logistic regression for the solar cluster, linear regression for the appliances cluster, and binary logistic regression for the efficient temperature system and efficient car measures. Intentions to install infrastructure for each cluster was also examined using linear regression. All analyses controlled for social desirability. Summary results are presented in Table 3.

Across these analyses, higher LCRI was associated with both possession of low carbon infrastructure and intentions to acquire it; the lack of relationship between LCRI and possession of an energy-efficient car was the only exception. In contrast, neither NEP nor belief in human-

caused climate change was associated with infrastructure possession or intentions. Climate change knowledge predicted solar intentions, possession of an efficient car and greater possession of efficient appliances.

3.4.4 Daily routine

Linear regression analysis was used to examine whether LCRI and comparison measures could predict low carbon daily routines and intentions. Again, all analyses controlled for social desirability; summary results are in Table 3. Higher LCRI was significantly and consistently associated with both past and intended performance of low carbon daily routines. The same results were found for NEP and climate knowledge measure; however, belief in human-caused climate change was unrelated to both past and intended practice within the temperature curtailment cluster.

Table 3. Study 2: Low carbon practice and intention predicted by LCRI and comparison measures

	LCRI				NEP				CC knowledge				CC belief			
	Behaviour		Intention		Behaviour		Intention		Behaviour		Intention		Behaviour		Intention	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Solar[a] (1 element)	0.35*	0.16	0.31**	0.10	0.07	0.15	0.08	0.10	0.23	0.15	0.24*	0.10	0.24	0.32	0.36	0.22
Solar[a] (2 elements)	0.74**	0.28			0.09	0.15			0.36	0.27			0.48	0.55		
Appliances	0.30**	0.09	0.39***	0.09	0.11	0.10	0.01	0.10	0.23*	0.09	0.14	0.10	0.03	0.20	0.20	0.21
Temp. system	0.14**	0.14	0.32**	0.11	-0.25	0.14	-0.05	0.11	0.01	0.14	0.11	0.12	-0.25	0.29	0.47	0.26
Car	0.14	0.19	0.30**	0.11	-0.02	0.18	-0.08	0.11	0.48*	0.21	0.14	0.11	0.52	0.42	0.21	0.23
Temp. Curtailment	0.28***	0.06	0.35***	0.06	0.23***	0.06	0.16**	0.06	0.17**	0.06	0.24***	0.06	0.12	0.13	0.22	0.13
Green travel & pay.	0.47***	0.06	0.62**	0.07	0.17*	0.07	0.31***	0.08	0.25***	0.07	0.27**	0.08	0.56***	0.14	0.69***	0.16

[a]Solar multinomial regression reference category = 0 elements.
*p<.05, **p<.01, ***p<.001

3.5 Discussion

Across Studies 1 and 2, LCRI showed good convergent validity with comparison measures, and in Study 2 it was uncorrelated with social desirability. LCRI was also shown to be a significant predictor of reported low carbon behaviour and intention, both in terms of infrastructure possession and daily routines. It was noticeable that NEP and climate knowledge were less predictive than LCRI, only predicting daily routines. It may be that the more general beliefs tapped by these measures were sufficient for predicting easier behaviours like temperature curtailment while the personal striving of a low carbon goal, as captured by the LCRI, is needed to motivate investment in infrastructure.

LCRI failed to predict one reported low carbon behaviour; possession of an energy-efficient car. This is unsurprising because it is a specific behaviour and is therefore not measured at the same level of specificity as LCRI and this type of incompatibility in level of specificity between predictor and outcome can be expected to reduce the correlation. As Stradling, Meadows, and Beatty (2000) found, there are many different motivations and relevant factors affecting different people's driving decisions (e.g. income). However, we did find that around two thirds of people with an energy efficient car have at least one other car that is not energy efficient, suggesting that further research focussed on cars could potentially examine the transition from one to all cars in a household being energy efficient.

Together, Studies 1 and 2 showed initial evidence for the construct validity of LCRI as a predictor of reported low carbon behaviour. However, replication in a large and diverse sample is desirable to confirm the robustness of these findings. In particular, the people sampled in Studies 1 and 2 included both homeowners and renters on the rationale that, although renters could not directly modify all forms of home infrastructure the way that homeowners could, renters were

able to select accommodation on the basis of existing low carbon infrastructure in the home (including efficient heating, solar panels and solar hot water). However, because homeowners have a much greater ability to modify major household infrastructure, we decided to control for this factor in Study 3.

4. Study 3

Study 3 tested associations between LCRI and clusters of reported low carbon behaviours using a large representative sample of the Australian population. To begin to account for the practical factors and competing priorities that limit the successful pursuit of a low carbon goal, we examined the LCRI-behaviour relationship while controlling for potential confounds including demographic factors, perceived resources and importance of household comfort. We also conducted a latent class analysis to explore the possibility that there may be different classes of respondents who engage with different behavioural clusters and examined LCRI's relations with the classes.

4.1 Method

4.1.1 Participants & procedure

Seven-hundred-seventeen Australians aged 18 years and over participated. They were contacted by telephone by the Swinburne University of Technology's telephone interviewing facility; 716 participants completed the survey immediately, while one completed an online version at a later date. Note that some questions were panelled; panel 1 (n=239) included questions about temperature systems and temperature curtailment, and panel 2 (n=237) included all reported routine behaviours and efficient car intentions. (For more detail on recruitment, study design and sample characteristics see Supplementary materials).

4.1.4 Demographic characteristics

Participants reported their household size, age, gender, place of birth, language spoken other than English, whether in paid work, and household income. Participants were also asked whether they resided in a house and whether they owned their own home (coded as 1 for own house, else 0). Again, we included the climate change belief measure.

4.1.5 LCRI and quality of life goal

LCRI (Cronbach's α = .84; M=3.81, SD=0.91) was measured and calculated as Study 1, as discussed in the Supplementary materials, this was then deemed the preferred method of calculation for the LCRI. We also gauged the quality of life goal: "living in a comfortable and attractive home" on a scale of 1 (Not at all important) to 5 (Extremely important).

4.1.6 Resources

To measure participants' perceptions of having surplus time, and finances, they were asked how often they had 'Time left over to just relax after meeting your responsibilities', with six response options (Never; Rarely; Sometimes; Often; Very Often; Always) and whether they agreed with the statement, 'Our household income is high enough to satisfy nearly all our important desires' (Strongly disagree; Disagree; Neutral; Agree; Strongly agree).

4.1.7 Current infrastructure and routine low carbon behaviour

Participants were asked to report their current infrastructure and routine low carbon behaviour with the same question stems as in Study 2, using the items and response options listed in Table 2. The distribution of raw responses is provided in the Supplementary materials. For infrastructure items, typically only a small proportion of participants selected the 'don't know' option and it was collapsed with the 'no' responses for analysis (coded 0) because the LCRI was designed to predict the purposeful acquisition of low carbon infrastructure (i.e. 'yes' responses, coded 1).

4.1.8 Intentions

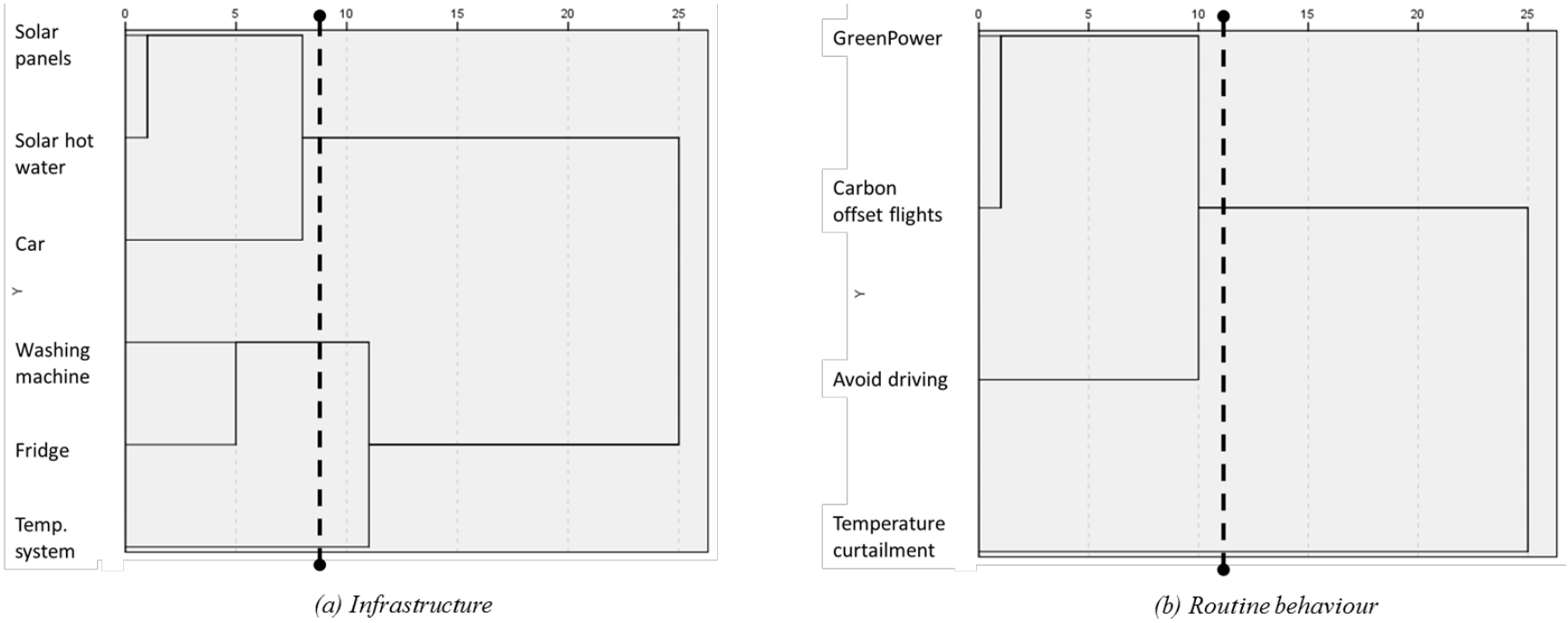
Intentions were measured in the same way as in Study 2, except that responses were recorded on a 5-point Likert scale (Definitely do not intend; Probably do not intend; Undecided; Probably do intend; Definitely do intend).

4.1.9 Constructing behavioural clusters

Dichotomous infrastructure measures were submitted to clustering as in Study 2 (see Figure 2 (a)). Two clusters were identified: solar and appliances. Summary measures were calculated as in Study 2. Temperature system did not cluster as closely with the other measures so it was examined by a single item. Efficient car was also examined by a single item (for comparability with Study 2 and due to low correlations with the solar items; $r=.09$, $p<.05$ with hot water and $r=.19$, $p<.001$ with solar panels).

To minimise the length of the survey, a single item was used as a summary measure of the past temperature curtailment cluster identified in the previous study. To capture the green payments and travel practices cluster, three routine measures were averaged (GreenPower, avoid driving a car, carbon off-set air trips; Cronbach's $\alpha = .54$). Although the Cronbach's α was low, the cluster summary measure was made because the division between the temperature curtailment cluster and the travel and payments cluster was supported by hierarchical clustering of the routine measures, dichotomised at their mid-point (see Figure 2 (b)).

Summary measures of intention were calculated by averaging the intention items that paralleled the behaviour items for each cluster (Cronbach's α for solar =.72; appliances = .70; green payments and travel = .55).



(a) Infrastructure *(b) Routine behaviour*

Figure. 2. Study 3: Hierarchical clustering of reported infrastructure and routine behaviour with Ward's Method

4.1.10 Classes of respondents with different infrastructure possessions

Finally, we looked for classes of respondents who possess different types of infrastructure. Mplus was used to conduct a latent class analysis of the infrastructure measures. The best solution extracted three latent classes (three classes BIC= 4841.35; two classes BIC= 4863.39; four classes BIC= 4874.89). As shown in Table 4, the three classes possessed advanced, intermediate or beginner levels of low carbon infrastructure (more discussion of classes is provided in the Supplementary materials).

Table 4. Study 3: Latent class analysis probability estimates for possession of different types of infrastructure

	Class		
	Advanced	Intermediate	Beginner
Percentage	26.08	39.05	34.87
N	187	280	250
	Probability of element		
Solar panels	.72	0	.27
Solar hot water	.58	.15	.33
Car	.70	.38	.21
Fridge	.68	.71	.19
Washing machine	.71	1	.15
Temp. system	.91	.73	.42

4.2 Results

4.2.2 LCRI prediction of clustered low carbon behaviour and intention

A series of regression analyses were conducted to assess the association of LCRI with behavioural clusters and intentions. Tables 5 and 6 summarise effects for behaviours and intentions respectively; for more detail see the Supplementary materials.

Within the solar cluster, the LCRI significantly predicted having two elements of solar technology compared to none; however, it did not differentiate having one element versus no

element of solar technology. LCRI also predicted the possession of efficient appliances (one or two elements compared to none), efficient car, practising temperature curtailment and making green travel and payments. It did not predict possession of an efficient temperature system. In addition, LCRI predicted intention to acquire both solar technology and efficient appliances, and intention to establish low carbon routines within the temperature curtailment cluster. It did not predict intention to acquire an efficient temperature system or car, nor to establish routines in the green travel and payments cluster.

4.2.3 LCRI prediction of the different classes of infrastructure possession

Multinomial logistic regression was used to assess the association between LCRI and infrastructure class membership (see Table 5). The advanced class was found to have significantly higher LCRI than both the beginner and intermediate classes. However, LCRI did not differentiate the beginner and intermediate groups.

4.2.4 Effects for covariates predicting clusters and classes

The comfortable and attractive home goal significantly and positively predicted both in the practice of and the intention to use an efficient temperature system. The only other effects for this predictor was that it negatively predicted past temperature curtailment. House ownership predicted both practice and intention for the solar and temperature system clusters. Age and household size also had a number of significant effects, although not consistently across practice and intention.

In terms of the infrastructure classes, the advanced class were more likely to be homeowners compared to both intermediate and beginner classes. Compared to the beginner class, they were also more likely to work, be older, have spare time, have spare money and be

female. Similarly, when people in the intermediate group were compared to people in the beginner group they were older, more likely to work and lived in small households.

Table 5. Summary of effects for regressions predicting low carbon behaviours

	Relative risk ratio (Multinomial)				*Odds ratio (Logistic)*		*Semi-partial r (Linear)*		*Relative risk ratio (Multinomial)*		
	Solar		Appliances		Temp. system	Car	Temp. curtail ment	Green travel & paym.	Infrastructure class		
	ref:0				*ref:0*				*ref: Beginner*		*ref: Inter.*
	1	*2*	*1*	*2*					*Advan ced*	*Inter mediate*	*Advan ced*
LCRI	1.16	1.37*	1.46***	1.63***	.85	1.30***	.33***	.35***	.85*	.71	.84**
Comf. & attractive home goal	.95	.96	.85	1.06	1.75**	1.02	-.09*	-.05	1.10	.96	.87
Surplus time	1.09	1.12	.95	1.23**	.81	.92	–	–	.95*	.85	.90
Surplus finances	1.00	1.30*	1.10	1.12	1.48	1.13	-.05	.06	.90*	.81	.90
Own house	2.57***	5.13***	.88	.88	1.84*	1.21	-.06	.05	.30***	.38	1.24***
Household size	1.04	1.14	.95	.81**	1.16	.98	.03	-.11	.74	.97*	1.31
Age	1.06	1.24	1.15	1.48***	1.02	1.47***	-.04*	-.01	.79*	.64*	.81
Female	.89	.77	1.00	1.57*	1.07	.98	-.01	-.01	1.24*	.79*	.64
Immigrant	1.35*	1.18	1.21	1.07	1.47	1.14	.02	.03	.66	.73	1.11*
Multi-lingual	.75	.91	1.58	1.54	.94	.80	-.02	-.05	1.03	1.04	1.01
Paid work	.62*	1.06	1.61	2.49***	1.74	1.37	-.07	.12*	.84**	.38*	.45
Income	.98	.92	1.07	1.22	1.24	.99	.04	.06	1.12	1.03	.91
Climate change belief	.51***	.84	.88	.87	1.07	1.11	.01	-.07	1.32	1.17	.88
Constant	.67	.08***	1.12	.70	.92	.49**			3.52***	6.44	1.83***
R^2	.07		.06		.12	.05	.14	.25	.07		

*p<.05, **p<.01, ***p<.001.

Table 6. Semi-partial r values from linear regressions predicting low carbon intentions

	Solar	Appliances	Temp. system	Car	Temp. curtailment	Green travel & payments
LCRI	.15*	.18*	.07	.07	.21***	.10
Comf. & attractive home goal	.04	.06	.16**	.07	.06	.03
Past practice[a]	.04	.10*	-	-	.31***	.49***
Surplus time	.02	-.03	-.18**	.13	-.02	.02
Surplus finances	.01	-.04	-.22*	.04	-.05	.05
Own house	.18***	.01	.12	-.05	.00	.01
Household size	.02	-.01	-.02	-.01*	-.03	-.09*
Age	-.10*	-.12	-.19	-.10	.00	-.15*
Female	-.03	.00	-.23	-.15	.02	.06
Immigrant	-.06	.04	-.11	-.04	.03	.04
Multi-lingual	-.01	-.04	-.03	-.03	-.05	.01
Paid work	.06	-.01	-.07	.16	.03	.06
Income	-.01	-.04	.03	-.10	.07	.03
Climate change belief	.02	-.03	-.11*	-.01	.05	.06
R^2	.09	.08	.26	.14	.24	.44

*p<.05, **p<.01, ***p<.001.

[a]Past practice refers to each intention's behavioural measure, included as a covariate.

4.3 Discussion

Study 3 again showed that the LCRI can predict activity within clusters of low carbon behaviours and intentions, both in terms of infrastructure possession and daily routines. The exceptions to this pattern of results again concerned narrow measures of reported behaviour (temperature system and car). However, LCRI differentiated the infrastructure classes, which incorporated all types of infrastructure possession into a single measure.

Study 3 replicated the core results of Study 2 with a larger national sample, while adjusting for a range of contextual factors, including financial resources and income. Future research examining LCRI's prediction of low carbon behaviour will seek to identify any patterns of spillover between different types of low carbon activity.

While the predictive power of LCRI was robust in Study 3, some contextual factors also stood out as important, especially house ownership. Those who do not own a house cannot modify it at will, and therefore personal strivings cannot guide the behaviours that are not under the control of type 2 processes. There were also indications, particularly for the infrastructure classes, that people are more likely to engage in low carbon living in later stages of life. The results confirmed our expectation that LCRI can predict generalized measures of reported low carbon behaviours and intentions. However, measurement constraints meant that the studies thus far concerned reported rather than actual behaviour. We now turn to actual behaviour in Study 4.

5. Study 4

Study 4 examined LCRI's capacity to predict an aggregate measure of a large number of actual low carbon behaviours, namely, average daily energy use.

5.1 Method

5.1.1 Participants & procedure

Ninety-six adults (47 female) aged 29 to 85 years (M_{age} = 51.12; SD_{age} = 11.54) participated. These people were members of a pre-existing study called the 'Residential Buildings Study'(RB study: Ambrose, James, Law, Osman, & White, 2013), which monitors actual household energy consumption, conducted by the Commonwealth Science and Industrial Research Organisation (CSIRO), an Australian Government agency. In September 2015, we recruited participants of the RB study who agreed to complete a survey either over the telephone (n=93) or online (n=3). Survey responses had 0-2% missing data except for income (6.59%). To avoid loss of power, missing data were imputed using Expectation Maximisation (Enders, 2001) in SPSS 22.

5.1.3 LCRI and demographic characteristics

LCRI was administered as in Study 1 (Cronbach's α = .83; M=3.82, SD=0.78). Participants also reported their household size, gender, age and income level (Under $31,200; $31,200 to just under $52,000; $52,000 to just under $78, 000; $78,000 to just under $130,000; $130,000 or more). The conditioned floor area of the home was measured by CSIRO researchers.

5.1.4 Energy use measures

Regardless of behavioural patterns of energy use, the size of the home and the number of people the home will inflate the amount of energy consumed. Preliminary analysis indicated that there were three home types: (1) Less than 4 people, area less than 152.20 sqm; (2) Less than 4 people, area 152.20 sqm or more; (3) 4 or more people. Electricity consumption (kW) was measured using a logger connected to the house mains switch board and hourly data were aggregated into average daily consumption for (a) week days, and (b) weekend for two time periods: time 1 and time 2, three months (June, July, August) before and three months (December, January, February) after the survey (September, 2015), respectively. To preserve

degrees of freedom in the analyses, the energy measures were then normalized by home type (see Supplementary materials for more detail).

5.2 Results

To examine the association between the LCRI and actual energy consumption we conducted three linear regressions. As shown in Table 7, time 2 general power consumption was strongly predicted by time 1 energy consumption. However, even controlling for time 1 general power consumption, there was a significant association between LCRI and time 2 general power consumption for both weekday and weekend consumption. Those with a higher LCRI tended to consume less energy. The demographic characteristics controlled for were not significantly related to time 2 general power consumption.

Table 7. Study 4: Beta coefficients for linear regressions predicting time 2 energy consumption with the LCRI

Model	Predictors	General consumption	
		Week day	Weekend
1	LCRI	-.24*	-.21*
2	Time 1 energy consumption	.75***	.79***
3	Time 1 energy consumption	.74***	.78***
	LCRI	-.14*	-.15*
	Age in years	-.07	-.04
	Female	.03	.03
	Income	.02	.05

*p<.05, **p<.01, ***p<.001

5.3 Discussion

Study 4 found that higher LCRI predicted lower general energy consumption. This finding dovetails with the previous studies to suggest that having a stronger low carbon goal will

inform behaviour across a range of different low carbon behaviours, resulting in real reductions in energy consumption. Future research examining the LCRI and actual energy consumption will examine the relative impact of different low carbon behaviours and also employ longitudinal modelling to confirm the robustness of the associations found here.

6. General discussion

Transformation to low carbon living requires a change in lifestyle. Four studies provided evidence for the construct validity of Low Carbon Readiness Index (LCRI), a short psychological measure that predicts a wide range of diverse low carbon behaviours in the household, and that can index general willingness to transition to low carbon lifestyle.

When LCRI items were subjected to principal component analysis, they consistently loaded on a single component with high levels of high internal consistency across samples. Study 1 provided evidence of convergent validity, showing that LCRI is associated with established predictors of environmentally significant behaviour (NEP, environmental identity and environmental striving), and belief in human-caused climate change. Although they could not speak to causality, both Studies 2 and 3 supported LCRI's construct validity by showing that personal goals to reduce carbon emissions predict greater reported engagement with low carbon behavioural clusters. Finally, in Study 4, LCRI was shown to predict general energy use after it was measured, even while controlling for the general energy use before its administration. We believe LCRI can be used to monitor population-level willingness to transition to low carbon lifestyle and to evaluate programs and policies to facilitate such cultural transformation.

However, both LCRI and the research so far have limitations. First, across all studies, participants consented to participate knowing that the study concerned low carbon behaviours. There is therefore a risk that the results are affected by participant self-selection into the studies.

However, in each study around a third of participants did not believe in human caused climate change and this is a similar proportion found by other surveys measuring climate change beliefs in the Australian population (Leviston, Greenhill, & Walker, 2015; The Climate Institute, 2016). Further, Study 3 found that the relationships between the LCRI and low carbon practice were robust even when adjusting for belief in human caused climate change. Consequently, we can be reasonably confident in the results reported.

Second, LCRI measures general personal goals to reduce carbon emissions, and therefore is expected to be associated with the engagement with clusters of low carbon behaviours rather than the adoption of specific low carbon behaviours. As the RAA suggests, not all low carbon-motivated people take the same low carbon actions, so a general measure is not well-suited to predicting a specific low carbon behaviour. Consistent with this principle, in our results specific reported behaviours (concerning temperature system and car) were not consistently predicted in the way that behavioural clusters were. It is likely that broader clusters of multiple behaviours would be needed to show the relationship between the LCRI and temperature and travel related behaviours.

Third, although the behavioural clusters examined here covered a wide range of infrastructure and daily routine activities, many other potential low carbon behaviours such as shopping and waste management are yet to be examined. Scales summarising the green payments and travel cluster may have had relatively poor reliabilities because the comprising behaviours more closely cluster with behaviours like green purchasing and waste management that were not examined in these studies. Furthermore, geographical and cultural factors may affect the structure of any behavioural cluster. The low carbon behavioural clusters and classes found here were similar to those found in other Western and European countries, with the solar,

appliances and temperature curtailment clusters seeming particularly cross-nationally relevant. However, these behavioural clusters are empirically derived, and sensitive to unknown contextual factors. Given the consistent results found across diverse behaviours in this paper, we expect that the relationship between LCRI and low carbon behavioural clusters will replicate across countries regardless of local variations in the clustering structure. However, identifying local variation in clustering should be a part of future research using LCRI to predict low carbon behaviour.

Finally, the brevity of the LCRI means that it does not give insight into the dynamics between the practical constraints and competing priorities that affect the successful performance of low carbon behaviour. For example, in Study 3 we controlled for several potentially relevant factors and found that home-ownership was associated with the installation of solar technology, highlighting the importance of actual control based on competence and resource considerations when promoting a low carbon lifestyle. In Study 3 we also found that a comfortable and attractive home was positively associated with the installation of efficient temperature systems but negatively associated with temperature curtailment. Such findings point to the diverse ways that other personal strivings may variously complement or compete with different low carbon behaviours and are worthy of further investigation (Axon, 2017).

Keeping these caveats in mind, the LCRI is a useful tool for researchers and practitioners seeking to promote low carbon living. While many psychological measures have some association with low carbon behaviour (e.g. climate change concern, environmental identity or environmental values) the LCRI is valuable for its direct relevance for GHG emission reduction, as well as its brevity and simplicity. Most existing scales are broadly concerned with the preservation of the natural environment, and not specifically with reducing GHG emissions.

Given that not all pro-environmental behaviours can reduce GHG emissions (e.g., saving a beached whale), and that not all GHG reducing behaviours may be necessarily seen to be pro-environmental (e.g., support for geo-engineering the atmosphere), we believe it is useful to have a scale specifically designed to measure personal goal strengths for reducing GHG emissions. This permits a more targeted measurement of public engagement with the climate change issue and its mitigation.

The LCRI can be easily included in any investigation if researchers wish to explore the relevance of their research for climate change mitigation and can be used at a minimum cost in designing, implementing, evaluating, and revising the diverse range of climate change policies available. In terms of public engagement, the three-item LCRI places a negligible burden on the general public and can predict a wide range of their low carbon behaviours. It is consequently a valuable tool for gauging public engagement. First, when designing a policy for climate change mitigation, the LCRI can be used to determine the specific policy objective (Peters, Fudge, & Sinclair, 2010). If the target community is not currently engaged with low carbon living (i.e., low LCRI), a policy may need to be designed to persuade the public for the importance of GHG emissions reduction; if it is already engaged (i.e., high LCRI), campaigns may be best designed to show the public *how to perform the behaviours* that can reduce GHGs, to inform *how effectively they can reduce GHG emissions,* and to provide *material and other resources for performing them* to reduce their difficulty, i.e., to reduce the barriers for engaging with low carbon behaviour clusters (Axon, 2017). In the implementation phase, the LCRI may be used to decide on the communication strategies for the policy. If the community is highly engaged with low carbon living (high LCRI), the policy may be best framed as a climate change mitigation measure; however, if it is not (low LCRI), the policy may be better framed as something else,

e.g., an energy saving initiative. Finally, LCRI can be deployed inexpensively to monitor whether and how much the campaigns and policies are having, or have had, an effect on the public engagement by taking measurements before, during and after implementation of any policy. This information may be used to continue, revise, or terminate those campaigns and policies. Thus, the LCRI can be used to gauge a population's general willingness to transition to low carbon lifestyle, and it can aid monitoring, policy making, and policy implementation in the context of climate change and energy consumption.

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