

Low carbon innovations for mobility, food, homes and energy: A synthesis of consumer attributes

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Abstract

Novel consumer goods and services in mobility, food, homes and energy domains are needed to help mitigate climate change. Appealing attributes of low carbon innovations accelerate their diffusion out of early-adopting segments into the mass market (1, 2). In this paper we synthesise insights on the attributes of low carbon consumer innovations across multiple domains. Using a directed literature review and content analysis, guided by Levitt's hierarchical ring model which distinguishes core from non-core attributes, we identified over 170 relevant studies across mobility, food, homes and energy domains. We extracted a set of 16 attributes generalisable to low carbon innovations across multiple domains of consumption, with the exception of energy innovations which appeal on a reduced set of attributes. Using multi-dimensional scaling techniques we found the appeal of non-core attributes varies between domains but core attributes are consistent across domains in line with Levitt's theory. As examples, low-carbon consumer innovations within mobility and food domains share non-core attributes related to improved private and public health, whereas innovations within food and home domains share non-core attributes related to technology acceptance and usability. We develop these findings to argue that many low carbon consumer innovations are currently positioned to appeal to a distinctive but limited group of early adopters who value novelty and climate benefits. To achieve mass market diffusion, product and service development, policy interventions, and communication strategies should focus on enhancing a wider set of attributes to broaden consumer appeal.

Highlights

Directed review distinguishes between core and non-core attributes for low carbon innovations;
Low carbon innovations across different domains share core attributes;
Innovations within mobility and homes domains cluster against distinctive non-core attributes;
Low carbon innovations in the energy domain have limited appeal across all attributes;

Keywords: low carbon consumer innovations; attributes; diffusion; directed review; mobility; homes; food; energy

Word Count: 10,985 (including appendices)

List of abbreviations

AVs	autonomous vehicles	b2c	business to consumer
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EVs	EVs	HEMs	home energy management system
MaaS	mobility as a service	NEVs	neighbourhood EVs
p2p	p2p	V2G	vehicle to grid

1.0 Introduction

Marketing and diffusion research emphasise the importance of product attributes to consumer adoption. Attributes are dimensions or characteristics of a product or service, perceived by consumers to satisfy a particular need or solve a particular problem (2-4). They are important because they determine rates of diffusion (1), they provide signals to consumers with respect to competing offers (2), they are the basis on which specific offers can be positioned and targeted to relevant consumer groups (2). In diffusion research differing consumer preferences for attributes are a key factor within the adoption process. In diffusion of innovations theory, Rogers (1) identifies important differences between early adopters attracted to novel attributes that highly differentiate products and services from mainstream offers and early and late majority consumers who require the reassurances that familiar and more mainstream attributes offer. In the UK there are many consumer-focussed low carbon innovations well positioned to appeal to the needs of early adopters. In his stylised model of the distribution of market share across consumers groups, Rogers (1) suggests that early adopters make up only around 16% of the potential market. For significant CO₂ reductions to occur in key consumer segments such as mobility and food, diffusion needs to occur beyond this niche. One of the major challenges relates to understanding how low carbon innovations appeal to a wider range of consumers.

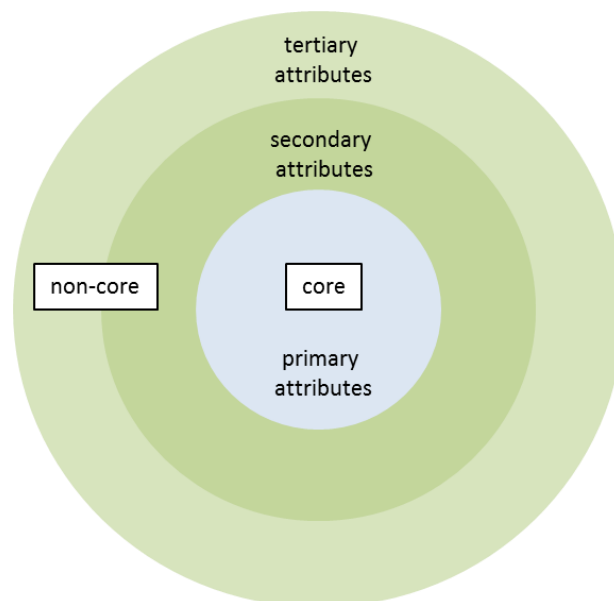


Figure 1 - The Levitt Ring Model (1984, 1980)

In marketing many conceptual models exist which categorise attributes, enabling deeper insights into the specific appeal of products and services to different consumer types. One of the most commonly used and adapted within marketing literature is Levitt's ring model (3) (Figure 1). This model consists of three layers or rings distinguishing between primary, secondary and tertiary attributes. The inner ring consists of primary attributes. These are core attributes that incorporate the essential and fundamental features of products and services that satisfy very generic needs (4-

7). For example hotels need to provide a safe and secure environment (4, 8, 9), public transport needs to be accessible and easy to use (5). Primary attributes generally offer nothing novel relative to competing offers yet Levitt's model shows they are core part of the offer. They are necessary but not sufficient. This emphasis is supported by many empirical studies into both high and low technology products and services (6, 9, 10).

The outer two rings in the Levitt model consist of secondary and tertiary attributes which are more distinguishable from the core primary attributes. Secondary attributes are additional, anticipated features that embellish or add value to the core (2, 4, 5, 11). In contrast with primary attributes secondary attributes are closer to luxuries or wants rather than needs (12). In addition to private mobility, private vehicles offer a range of secondary attributes such as additional design features (13). Washing machines are valued more by consumers when the value proposition includes not only primary attributes such as cost and basic functionality but secondary attributes such as improved controllability and energy efficiency (11). Tertiary attributes relate to more unique, distinguishable and unanticipated problem solving features that are novel compared to the competition. Tertiary attributes have high appeal to early adopters who value this novelty (5, 6). In their study into the valued attributes of instant messaging services, Lee, Khan (6) find a particular unexpected tertiary attribute is connectivity. This has high saliency with early adopters.

Many empirical studies use a reduced form of the Levitt ring model to concentrate on the differences between core and non-core attributes. In these studies core attributes are defined as utilitarian, functional, or instrumental. Non-core attributes are defined as hedonic, symbolic or facilitating (4, 11-14) (see Appendix A, Table 6). Since its introduction there have been many interpretations and applications of the Levitt ring model within marketing and consumer behaviour studies. Kotler and Armstrong (2) suggest the three levels clearly distinguish between layers of added value in which tertiary attributes are equivalent to an augmented product offering which is highly distinguishable from incumbents. Kano, Nobuhiko (15) develop the model to distinguish between product and service features that highly influence consumer satisfaction. Using a compatible framing between core and non-core attributes this framework determines which attributes are 'must haves' in the eyes of the consumer (8).

Although there are competing views as to whether core attributes are more important to consumers than non-core attributes (5, 6), there is strong evidence that core attributes are an essential part of the value proposition. In their empirical study of the valued attributes of high technology products Lee, Khan (6) find although early adopters place more value on tertiary level attributes, core attributes moderate adoption propensity. Other studies similarly find that whilst core attributes are not strongly related to overall satisfaction they can become dis-satisfiers if products and services perform badly against them (4, 5, 8, 9, 16). In their study into household washing machine purchases in China, Wang, Lu (11) find that a few basic, core attributes such as ease of use and convenience account for the majority of post purchase consumer satisfaction ratings.

Empirical research focussing on the attributes of low carbon innovations has historically focussed on single domain, single innovation studies. For example comparing single innovations (such as EVs), against the incumbent technologies (conventionally fuelled vehicles). They focus on comparing the core attributes of the incumbent technology (such as costs and performance) with the environmental benefit of the lower carbon alternative (such as lower emissions) (10, 17). This review

looks beyond low carbon as the sole attribute of low carbon innovations, exploring broader sources of added value across both core and non-core attributes. Applying the reduced Levitt framework to distinguish between these attribute types, this review takes a multi-domain, multi innovation approach, focussing on four key domains, all which require significant reductions in consumer based CO₂ emissions. These are mobility, food, homes and energy. The core contribution, apart from offering an up to date classification of the attributes of low carbon innovations, is to critically evaluate how low carbon innovations cluster within and across key consumer domains. In a final discussion this review evaluates how low carbon innovations might be positioned relative to distinctive consumer segments and identifies particular policy implications. These segments include consumers who value low carbon or other novel attributes and those that value more mainstream core attributes.

The aims of this review are twofold: to broaden understanding of the wide ranging attributes of low carbon innovations by clearly defining and identifying the core and non-core attributes; and to identify distinctive clusters of innovations across domains that share common attributes.

2.0 Analytical Framework

Products and services consist of a bundle of attributes which are differently valued by consumers (3). The Levitt ring model offers a simple but effective categorisation of attributes that can be easily applied across multiple consumer domains and across both high technology and low technology products and services. In basing a substantive literature review on this framework it is possible to capture attributes that are likely to appeal across multiple consumer groups and across multiple domains.

The analytical framework distinguishes between core and non-core attributes (Figure 2). Core attributes are a generic set of attributes which have broad appeal across a range of consumer domains and seen as an essential part of the overall product or service offering. Examples include safety, convenience, and low cost (18). In contrast non-core attributes include anticipated and unanticipated attributes where the latter relate to novel and unique characteristics of particular low carbon innovations or relate to an unexpected feature of low carbon innovations within a particular domain. Chitturi, Raghunathan (12) find consumers distinguish between the functional core attributes of private cars, laptop computers and mobile phones and facilitating non-core attributes of style and attractiveness. Slevitch and Oh (4), Slevitch, Mathe (8) find that 'greener attributes' are unanticipated within the hotel industry but contribute additionally to core functional and non-core facilitating attributes in terms of overall customer satisfaction.

To identify attributes the analytical framework draws on three key sources of information. Firstly empirical studies that directly apply the Levitt ring model to identify core and non-core attributes. These studies represent a wide range of consumer domains including high technology (instant messaging, mobile phones, laptops) (6, 12), household appliances (washing machines) (11), public and private mobility (public transport and private cars) (5, 12, 13) and public and private services (tourist destinations, food and hotels) (4, 8, 18). Secondly studies which although do not directly apply the Levitt model use a similar framing to distinguish between core and non-core attributes (10, 14, 19). For example Axsen and Kurani (14) identify a 2 x 2 attribute matrix that applies to mobility innovations. Although this matrix distinguishes clearly between private and public attributes it also clearly distinguishes between functional core attributes and more symbolic non-core attributes.

Thirdly studies that identify potential sources of consumer novelty from alternative models of product and service provision. This includes the sharing economy and service-based economy (20-22). These are important for low carbon innovations offering distinctive value propositions compared to mainstream incumbent technologies which mainly focus on the business to consumer retail model.

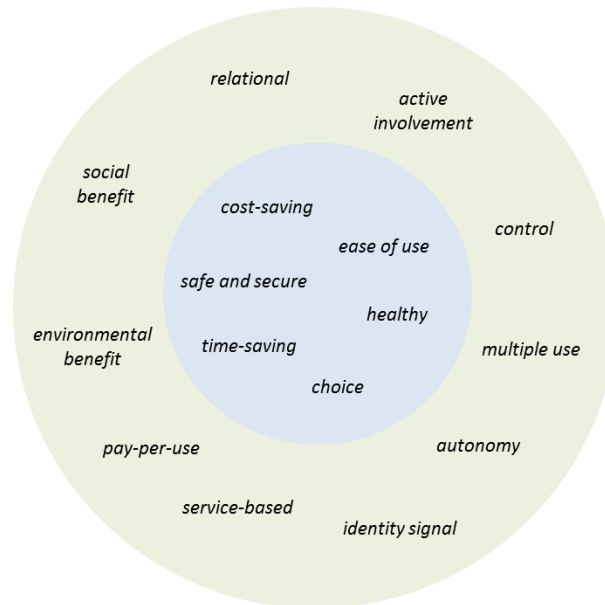


Figure 2 – The core and non-core attributes of low carbon innovations

At the centre of the analytical framework are 6 core attributes (Figure 2, blue circle). They relate to the functional, utilitarian needs of consumers. The outer ring of the framework consists of 10 non-core attributes (Figure 2 green circle). They relate to the hedonic, symbolic or facilitating needs of consumers. Attributes are defined as follows:

- '*cost-saving*', cost efficient, low or no cost, or enables money to be used productively
- '*time-saving*', time efficient, saves time, or enables time to be used productively
- '*healthy*', supports healthy living or positive health outcomes
- '*safe and secure*', provides security or is safe to use, low risk
- '*ease of use*', low hassle, easy to use, convenient, or easy to access
- '*choice variety*', allows users to choose alternative forms of the good or service to suit different needs or contexts
- '*environmental benefit*', low or no emissions (or other pollution) associated with the use of a product or service
- '*social benefit*', provides social or collective benefits shared by non-users
- '*relational*', involves direct or indirect interactions with others who either use or provide the product or service
- '*active involvement*', enables an active role or contribution by users to how a product is produced or a service is provided
- '*pay-per-use*', has a usage-based or subscription-based cost structure without the need for upfront capital or other one-off investments
- '*service-based*', useful service provided by a third-party without needing to own and maintain a product or technology
- '*multiple use*', provides a range of different functions or forms of use, economies of scope
- '*control*', provides control or gives users the ability to influence or manage how a product or service is used
- '*autonomy*', independent of other service providers, people or infrastructures of provision
- '*identity signal*', supports desirable aspects of users' individual or social identity and how this is communicated

This analytical framework (Figure 2) is used to address the following research questions:

1. Do low carbon innovations across four consumer domains share similar attributes?
2. Do low carbon innovations cluster against specific core or non-core attributes?

3.0 Material and methods

To answer these questions a category development approach described by Michelini, Principato (23) is used. This involves a form of directed review and content analysis of the literature, guided by a theory or as in this case a conceptual framing (24). The process consists of three clear stages (1) directed literature review and data collection (2) qualitative synthesis of attributes across domains and innovations (3) quantitative coding of attributes and testing for clustering across low carbon innovations.

The directed review process is driven by a set of keywords related to each individual low carbon innovation (see Table 1) plus each attribute identified in the analytical framework (see Figure 2). Keywords for low carbon innovations consist of a combination of alternative names or labels for specific low carbon innovations and specific examples. Attribute keywords are drawn from the detailed definitions of attributes, drawn from empirical studies (see Section 2). Boolean phrases are formed from these keywords to identify potential studies for synthesis. Phrasing follows the basic formula of 'attribute *OR benefit* AND (attribute-[specific]) AND (innovation-[specific]) OR [innovation-[specific-example]]' (See Appendix B Tables 7(a) to 7(c)).

A wide range of search engines are used to access both grey and published studies. These include Science Direct, Scopus, Business Source Complete, Google Scholar, government, industry and trade association websites, national and local press and other media websites, marketing trade and research websites including Mintel, Euromonitor, and Statista.

Selection criteria allows studies and articles which fall into one of four key types: (i) empirical studies in which attributes are derived from users, (ii) theoretical studies in which attributes are assumed, argued or conceptualised, (iii) policy, consultancy, or other reports in which attributes are identified, and (iv) industry marketing or other reports by industry actors (including media) in which attributes are debated or discussed.

For each study selected the following information is recorded: type of article/study, specific low carbon innovation(s) analysed or discussed, content related to specific attribute(s) including examples, applications, or critiques, their relevance to specific innovation(s) and indications of importance or strength of attribute in terms of its appeal to consumers and specific consumer segments.

3.1 Data generation

A total of 38 low carbon innovations are identified (see Table 1). These are selected based on earlier work by the authors, in which 99 potentially disruptive low carbon innovations were identified from a wide range of literatures (25, 26). The identification of 38 low carbon innovations used in this study is drawn based on the following criteria: they are consumer facing alternatives to major incumbents

or incumbent behaviours in one of the four key domains; they have some (included limited) presence in the marketplace. They include low carbon innovations based on the digital economy (online or app-based) and alternative models of provision. This includes the ownership versus service economy and centralised retailing versus the sharing economy. The selection includes at least one low carbon innovation in each domain based on the sharing economy. Across all domains different forms of the sharing economy are represented including the on-demand economy (e.g., car clubs), the second hand economy (e.g., p2p exchange of goods and services) and the exchange of under-utilised assets (e.g., ride sharing and food sharing) (27, 28) (See Appendix C, Tables 8(a) to 8(d)).

Table 1 – Low carbon innovations included in this study

domain	ref	Low carbon innovation	domain	ref	Low carbon innovation
mobility	T1	car clubs (US car sharing)	food	F1	digital hubs for local food
	T2	p2p (p2p) car sharing		F2	meal kits
	T3	ride sharing		F3	11 th hour apps
	T4	shared taxi (or taxibus)		F4	food pairing apps
	T5	mobility as a service (MaaS)		F5	food sharing
	T6	EVs (EVs)		F6	dietary change gamification
	T7	e-bikes		F7	food waste reduction nudges
	T8	autonomous vehicles (AVs)		F8	urban farming
	T9	neighbourhood EVs (NEVs)		F9	cultured meat
	T10	bike-sharing	energy	E1	domestic electricity generation with storage
	T11	telecommuting		E2	p2p electricity trading
	T12	videoconferencing and virtual meetings		E3	electric vehicle to grid
	T13	telepresence and virtual reality		E4	time of use pricing
homes	H1	smart heating systems	energy	E5	demand response
	H2	smart lighting		E6	energy service companies
	H3	smart appliances		E7	third-party financing
	H4	home energy management systems (HEMs)		E8	community energy
	H5	heat pumps			
	H6	prefab retrofits			
	H7	p2p (p2p) products and services			
	H8	real-time feedback on disaggregated loads			

In the mobility domain low carbon innovations selected (n=13) all have the potential to compete with private vehicle use including commuting between work and home or between workplaces or offices (e.g., e-bikes can be substituted for short distance commutes). They include those that offer service-based alternatives to vehicle ownership and those that replace or substitute the need for driving a privately owned vehicle to work or for business related travel (e.g., car clubs can replace the need for car ownership). In the food sector low carbon innovations chosen all compete with food shopping from large scale food retailers (n=9). These food innovations also have the potential to reduce food miles and food waste as well as lowering dietary related CO₂ emissions (e.g., digital hubs for local food provide a source of locally grown fruit and vegetables, grown on rooftops and sold in the supermarket below). In the homes sector innovations selected (n=8) help consumers to manage their energy demand (e.g., smart heating systems enable consumers to better manage the temperature and duration of heating schedules), improve home energy efficiency (e.g., HEMs) and reduce demand for new goods (e.g., p2p products and services). In the energy sector innovations relate to household energy generation, storage and use (n=8) and have the potential to improve

home energy efficiency, provide service-based alternatives to energy management, and enable households that generate their own electricity to trade with energy providers or other households.

3.2 Data analysis

The first research question asks “do low carbon innovations across four consumer domains share similar attributes?” To answer this question content data is extracted from articles and studies. In a first step each attribute’s relevance for each low carbon innovation is recorded using a simple coding scheme (where 1=evidence attribute is relevant and 0=no evidence attribute is relevant). In a second step the richness of the content data is used to identify cross cutting themes within each attribute that apply either across domains or across similar types of low carbon innovation. Identification of these themes draws on earlier work by the authors (29) (see Appendix D, Table 9). The second research question asks “do low carbon innovations cluster against specific core or non-core attributes? Building on steps 1 and 2 above, in a third step for each low carbon innovation the appeal of relevant attributes is estimated using a scale of 1 to 3 (where 1=low appeal, 2=modest appeal and 3=high appeal). This quantification is a subjective scoring based on evidence in the literature. A final fourth step uses multi-dimensional scaling (MDS). MDS is a mathematical technique which seeks to identify the underlying structure of data (30, 31). It is commonly used for understanding relationships between ‘objects’ (low carbon innovations) and ‘perceptions or attitudes’ (appeal of attributes) (32). The output of MDS models is typically in the form of a perceptual map. This plots the geometric distance between objects in a two dimensional space (31). The two dimensions of an MDS model are open to be interpreted and are not predefined (32).

Using statistical software (33), the relative appeal of the 38 low carbon innovations against 16 attributes is transformed into a proximity matrix. Proximities are the Euclidean or straight line distance between low carbon innovations based on their appeal within this reduced ‘attribute space’ (30, 31). Where MDS is performed subsequent to qualitative analysis, meaningful interpretation of the axes draws on the qualitative data to account for clustering within the same attribute space or those that sit in opposing quadrants of the perceptual map (32).

4.0 Results

A total of 274 studies were identified from the directed review. A final total of 171 articles and papers met at least one of the four inclusion criteria. Just under half were empirical studies (n=85), the remaining were either (theoretical) studies (n=29), government or policy related reports (n=4) or industry, marketing or other reports (n=53).

4.1 Qualitative evaluation of attributes

Table 2 – Relevance of core attributes and cross cutting themes for 38 low carbon innovations in 4 domains of consumption

id	attribute	evidence in domain	st	cross cutting themes within studies/articles	References
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		mobility	food	homes	energy		
core	<i>cost-saving</i>	x	x	x	x	44	'financial savings and lower costs', 'value for money' (34-78)
	<i>ease of use</i>	x	x	x		43	'convenience', 'accessibility', 'low hassle', 'flexibility', 'on demand', 'simplicity', 'easy to understand' (35, 38, 39, 43, 49, 51, 53-55, 57, 58, 66, 75-77, 79-106)
	<i>safe and secure</i>	x	x	x		21	'increased food security', 'safer food', 'personal and family security' 'avoid energy blackouts' (34, 43, 48, 57, 63, 74, 75, 87, 91, 98, 103, 107-116)
	<i>healthy</i>	x	x	x		31	'improved emotional and physical fitness', 'improved quality of life', 'healthier living and working environments', 'improved diet and nutrition' (44, 48, 53, 57, 68, 69, 82, 86, 90, 98, 100, 111, 117-135)
	<i>time-saving</i>	x	x	x		25	'reduces time', 'frees up time', 'more productive use of time' (34, 37, 43, 53, 57, 66, 69, 71, 74, 76, 86, 90, 98, 101, 126, 136-145)
	<i>choice variety</i>	x	x	x		30	'choice of use', 'choice of products', 'choice of suppliers' (34, 35, 38, 39, 45, 51, 53, 61, 62, 79, 80, 86, 87, 89, 92, 94-96, 101, 103, 117, 121, 133, 137, 140, 146-150)

Tables 2 and 3 summarise the results from the thematic analysis. Table 2 identifies the relevance of each core attribute across the four domains. It also identifies cross cutting themes. '*Cost-saving*' is the only core attribute common to all four domains. Across all other core attributes low carbon innovations within mobility, food and homes are widely perceived in the literature as having a similar core offering to consumers. '*Ease of use*' incorporates a number of consistent themes across domains including improved accessibility, reduced hassle, simplicity of use, and ease of understanding (76, 83). Improved accessibility is a particular cross cutting theme within this attribute relating largely to app-based innovations (81, 86, 88, 92). Other core attributes incorporate themes that demonstrate subtle differences between domains. '*Safe and secure*' varies between the public context in which mobility is consumed and the private context in which food and homes related innovations are used. AVs improve private security (34) but more localised food production secures public interest (food security) (112). Real-time feedback on disaggregated loads improves the management of peak energy and reduces the threat of energy blackouts (75). This distinction between private and public attributes is consistent with Axsen and Kurani (14) who suggest both core and non-core attributes for mobility innovations should be further categorised between private and public domains. '*Healthy*' has many interpretations across domains. Mobility innovations de-stress travel and working environments (69), and improve emotional and physical fitness (57, 98, 130, 151). Food innovations improve diet and nutrition (121, 152). Home innovations maintain healthy living environments particularly for vulnerable people (128). '*Time-saving*' is all about fulfilling a functional need to use time more productively on work or leisure. Mobility innovations reduce travel time, save time (reduce congestion) and reduce waiting times (particularly if app-based) (21, 138-140). Food and homes innovations reduce shopping time (74, 86), cooking time(90), and increase leisure time(153). '*Choice variety*' relates to both alternative forms of consumption and alternative forms of behaviour. MaaS offers choice between modes of travel (92) and digital hubs for local foods enhance choices between local foods (121). Videoconferencing and telepresence in contrast offer choice and flexibility in commuting behaviour (40, 148) and food pairing apps offer choice between using food for different recipes and wasting it (147).

Table 3 – Relevance of non-core attributes and cross cutting themes for 38 low carbon innovations in 4 domains of consumption

Category	attribute	evidence in domain				studies found (n)	cross cutting themes within studies/articles	References
		mobility	food	homes	energy			
non-core	<i>environmental benefit</i>	x	x	x	x	39	'lowers CO ₂ emissions and avoids pollution', 'avoids waste', 'builds more sustainable marketplaces and greener cities', 'reduces consumption'	(27, 34-36, 46, 50, 54, 57-59, 80-82, 86, 94, 106, 108, 125, 128, 137, 140, 142, 148, 150, 154-159)
	<i>social benefit</i>	x	x	x	x	34	'inclusive', 'help and support others', 'educate', 'enhanced local biodiversity and utilisation of space', 'builds communities', 'widespread common good', 'provides benefits to others'	(27, 34, 46, 49, 50, 66, 69, 76), Boxall (81), (86, 90, 91, 102, 103, 106, 117-119, 123, 126, 128, 145, 147, 148, 160-169)
	<i>relational</i>	x	x	x	x	27	'integration into a community', 'strengthens relationships', 'enhances or creates social networks'	(27, 37, 38, 50, 58, 67, 69, 74, 75, 87, 91, 100, 109, 114, 138, 148, 150, 170-172), La Trobe (173), (174-179)
	<i>active involvement</i>	x	x	x	x	23	'co-creation', 'sharing with others', 'self-reward framework', 'proactive management'	(38, 42, 43, 49, 53, 67, 70, 75, 79, 82, 88, 98, 106, 126, 128, 133, 150, 158, 169, 178-181)
	<i>pay-per-use</i>	x		x	x	20	'usage-based consumption', 'removal of upfront costs', 'access without ownership'	(34, 38, 57, 67, 74-76, 78, 80, 92, 94-96, 127, 160, 182-187)
	<i>service-based</i>	x		x	x	26	'third-party management', 'flexible usage'	(34, 35, 39, 50, 51, 53, 69, 74-76, 78, 80, 86, 90, 92, 94-96, 127, 147, 170, 183-185, 187, 188)
	<i>multiple use</i>	x	x	x	x	21	'additional services', 'access to multiple services'	(35, 37, 39, 42, 43, 46, 49, 58, 62, 69), The Energy Saving Trust (77), (80, 89, 91, 98, 103, 104, 126, 185, 189, 190)
	<i>control</i>		x	x	x	13	'improved monitoring', 'improved management', 'automation'	(39, 42, 69, 75, 100, 103, 128, 150, 181, 185, 191-193)
	<i>autonomy</i>	x	x	x	x	12	'independence', 'alternatives to major systems of centralised provision'	(36, 38, 86, 119, 125, 147, 174, 180, 185, 189, 192, 194)
	<i>identity signal</i>	x	x	x	x	26	'collective identity', 'environmental symbolism'	(10, 38, 43, 61, 69, 86, 90, 95, 113, 117, 119, 149, 150, 174, 176, 177, 180, 189, 195-202)

Table 3 identifies the relevance of each non-core attribute across the four domains, and related themes that emerge from studies. '*Environmental benefit*' is a common non-core attribute across all four domains, and this is entirely consistent with the framing of low carbon. Importantly other environmental benefits are common beyond lower CO₂ emissions, including pollution, waste, sustainability and lowered consumption (58, 81, 86, 115, 140, 177). '*Social benefit*' distinguishes between domains in which low carbon innovations offer greater public benefit. Mobility and food innovations contribute widely to public good, with themes related to social inclusivity (160, 163), improved public food education and local diversity (90, 161, 165). '*Relational*' and '*active involvement*' bring together low carbon innovations based on the p2p model with themes relating to improved physical integration within communities (170), formation of supportive online communities(67), friendships and cooperative consumption between family members, co-workers,

and within other close social networks (67, 138), and the creation of prosumers particularly in the context of ridesharing and p2p car clubs (38). *'Pay-per-use'* and *'service-based'* bring together low carbon innovations that offer an alternative to private ownership. This is reflected in themes related to usage-based and more flexible consumption (38, 76, 127, 160), access without ownership (95), and third-party management (188). Qualitative analysis confirms that there are few low carbon innovations that are *'multiple use'*. Some energy innovations provide additional grid services including distributed production as well as own consumption (192). Low carbon innovations across all four domains however, offer multiple benefits. E-bikes combine personal mobility over longer distances with the potential for improving health (126) and fully autonomous vehicles combine personal transport with the potential for a mobile office (189). NEVs provide additional mobility within parks, college campuses, and golf courses (37). Some food innovations combine dietary management with gaming and health tracking (53). *'Control'* and better management applies across food, homes and energy but is viewed as a key benefit of a small number of low carbon innovations within the homes domain which improve management and monitoring of energy use, and provide enhanced, real-time automation of household tasks such as switching on heating and lighting (39). *'Autonomy'* is also common to all four domains where it relates strongly to freeing consumers from providers. These include petroleum companies (14, 180), animal agriculture (125), food waste (147). Themes also relate to increased agency in terms of living more independently (128). *'Identity signal'* is a complex, symbolic attribute which varies between self-identification through private consumption and a social, collective identity from membership of a particular group or sub-group. Self-identities relate to low carbon innovations that help consumers to cultivate a positive self-image (177), symbolise ideas such as environmental preservation (180), inspire others to consume (14), or being seen by others to be an early adopter (93, 153, 180). Social, collective identities relate to alignment or membership of particular social groups. Car clubs for example are social organisations which offer a collective identity which has positive consequences for the consumer, including feelings of engagement and reduced normative pressure (195). Similarly many low carbon innovations in the food domain confer strong social identities for consumers who engage in more socially acceptable practices such as buying local food (86), cooking from scratch (90), wasting less food (149), and eating low meat diets (119, 174).

4.2 Quantitative evaluation of the appeal of attributes to potential consumers

Qualitative analysis identifies the extent to which attributes are relevant to low carbon innovations across four main consumer domains. In general the low carbon innovations across domains appeal right across the set of 6 core and 10 non-core attributes, although with differing emphasis. Low carbon innovations in the energy domain appeal on a narrower set of attributes. By scoring the extent to which each innovation appeals to consumers across attributes, the qualitative data is built upon to identify how low carbon innovations cluster according to their specific value proposition to consumers. Subjective, scorings are derived from qualitative findings within the literature. All scorings are double blind with differences between coders then resolved through discussion.

To examine the clustering of low carbon innovations against attributes two MDS models are run. The first model compares the relative positioning of all 38 low carbon innovations against the 16 core and non-core attributes. This model tests the hypothesis that low carbon innovations in the outer four quadrants of the perceptual map cluster against unique, non-core attributes. The second and subsequent model draws on the findings from model 1. Low carbon innovations proximal to the

centre of the two axes ($x, y=0$) in model 1 are more likely to appeal similarly against attributes shared by the 16 low carbon innovations. Model 2 tests this hypothesis using a subset of low carbon innovations and a subset of shared attributes identified in model 1.

The output from each MDS model is a perceptual map (Figures 3 and 4). The identification and explanation of clusters draws the quantified scorings of low carbon innovations against the attributes (see Appendix E, Tables 10(a) to 10(b)) and the qualitative findings (Section 4.1).

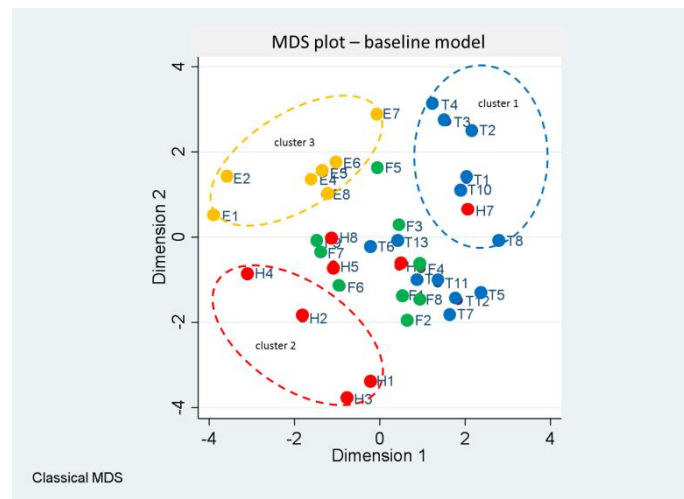


Figure 3 –Perceptual map 1 (model 1)
Outer quadrant clustering of low carbon innovations appealing against distinctive non-core attributes

Table 4 Low carbon innovations within clusters 1 to 3

cluster 1		cluster 2		cluster 3	
T1	car clubs	H1	smart heating systems	E1	domestic electricity + storage
T2	p2p car share	H2	smart lighting	E2	p2p electricity trading
T3	ride share	H3	smart appliances	E3	V2G
T4	shared taxi	H4	HEMs	E4	time of use pricing
T8	AVs			E5	demand response
T10	bike-share			E6	energy service companies
H7	p2p products & services			E7	third-party financing
				E8	community energy

note (blue=mobility, green=food, red=homes, yellow=energy)

Figure 3 is a perceptual map of the clustering of low carbon innovations within the full two dimensional attribute space. It shows the relative positioning of all 38 low carbon innovations, colour coded according to domain. Three clusters of low carbon innovations sit in the outer quadrants of the perceptual map. The top right corner cluster 1 (circled in blue) is dominated by low carbon innovations from the mobility domain. These are T1 (car clubs), T2 (p2p car share), T3 (ride share), T4 (shared taxi), T8 (AVs), and T10 (bike-share). Only H7 (p2p products) is included from the homes domain (see Table 4). F5 (food sharing) sits just outside this cluster. These low carbon innovations share many core attributes including ‘*cost-saving*’, ‘*healthy*’ and ‘*time-saving*’ and have high to moderate appeal against non-core attributes ‘*environmental benefit*’ and ‘*social benefit*’.

Unique to this cluster, however, is high to moderate appeal against non-core attributes '*pay-per-use*', '*service-based*', '*relational*' and '*active involvement*'. These low carbon innovations are all based on the sharing economy model, strongly associated with these non-core novel attributes (21, 22). Findings also suggest these more novel attributes are supported by a relatively strong core offering. Core attributes are an essential part of the value proposition to consumers and can become dis-satisfiers if they are not adequately met (4, 7).

Diametrically opposite cluster 1, a smaller cluster 2 (circled in red) is dominated by homes innovations. These are H1 (smart heating), H2 (smart lighting), H3 (smart appliances) and H4 (HEMs). They also share many core attributes, including '*cost-saving*', '*ease of use*' and '*safe and secure*'. These are important core attributes that are highly valued by mainstream consumers who value familiarity, trust and fit within current social practices (203). This cluster almost exclusively offers two non-core attributes '*control*' and '*multiple use*'. As with cluster 1, this is clearly linked to 'smart', technology-mediated control of domestic functions.

In the top left corner cluster 3 (circled in yellow) consists entirely of energy innovations. These low carbon innovations have a weak core offering and only appeal against '*cost-saving*'. This is indicative that these energy innovations fail to offer a compelling challenge to the mainstream model of passive energy consumers and centralised utilities. Solar PV, and EVs are expensive and subject to enabling infrastructure and regulation. Energy innovations in this cluster have distinctive non-core appeal particularly against '*autonomy*' where this relates strongly to providing consumers with alternatives to centralised utility supplied energy (185, 192).

In the centre of the perceptual map there are 19 low carbon innovations dominated by food innovations. These are all highly to modestly appealing against public, non-core attributes '*environmental benefit*' and '*social benefit*' but have low appeal against the other 8 non-core attributes relative to clusters 1 to 3. The second MDS model tests the hypothesis that these 19 low carbon innovations cluster on the shared attributes which include the 6 core attributes plus the two non-core attributes '*environmental benefit*' and '*social benefit*'. Core attributes such as 'low cost', 'ease of use', 'time-saving' are essential to mainstream consumers and are also attributes against which low carbon innovations can compete directly with incumbent technologies (3, 6, 7, 203).

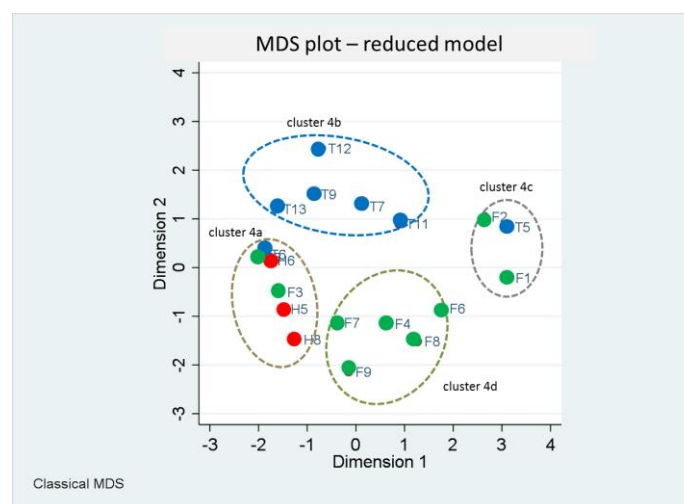


Figure 4 – Perceptual map 2 (model 2)

Outer quadrant clustering of low carbon innovations appealing against distinctive core attributes

Table 5 Low carbon innovations within clusters 4(a) to 4(d)

Cluster 4(a)		Cluster 4(b)		Cluster 4(c)		Cluster 4(d)	
T6	EVs	T7	e-bikes	F1	digital hubs food	F4	food pairing apps
F3	11th hour apps	T9	NEVs	F2	meal kits	F6	dietary change gamification
F5	food sharing	T11	telecommuting	T5	MaaS	F7	food waste nudges
H5	heat pumps	T12	video-conferencing			F8	urban farming
H6	prefab retrofits	T13	telepresence			F9	cultured meat
H8	real-time feedback						

Note (blue=mobility, green=food, red=homes, yellow=energy)

Figure 4 is a perceptual map showing the clustering of the reduced set of low carbon innovations (n=19) within a new two dimensional space. Clusters are identified based on their positioning within the outer quadrants of the perceptual map. Figure 4 shows four clusters, 4(a) to 4(d). Cluster 4(a) (circled in brown) is a cross domain cluster of six low carbon innovations. These are T6 (EVs), F3 (11th hour apps), F5 (food sharing), H5 (heat pumps), H6 (prefab retrofits) and H8 (real-time feedback). These all have very limited core appeal, appealing only against '*cost-saving*'. In this cluster there is a clear cross cutting theme of improved efficiency and reduced waste. For the homes innovations this relates to better use of energy and lower fuel bills, (46, 77). For mobility this relates to more efficient private mobility and lower running costs (36, 61). For food this relates to lowered food waste and lower food costs (65, 149).

In the top left corner cluster 4(b) (circled in blue) is a cluster of five alternative forms of mobility. These are T7 (e-bikes), T9 (NEVs), T11 (telecommuting), T12 (videoconferencing) and T13 (telepresence). These low carbon innovations have wider appeal across the core attributes (relative to cluster 4(a)) with moderate to high appeal against '*cost-saving*' and '*time-saving*' and some appeal against '*healthy*'. Particular cross cutting themes relate to reduced costs of travel (84), more productive use of time(70, 144) and reduced social costs where this relates directly to the health and social wellbeing of individuals and or employees (69)

Diametrically opposite cluster 4(a), cluster 4(c) (circled in grey) is a cluster of 3 low carbon innovations. In contrast to cluster 4(a) and 4(b), low carbon innovations in this cluster have low to no appeal against '*cost-saving*'. These low carbon innovations are F1 (digital hubs food), F2 (meal kits), and T5 (MaaS). Cluster 4(c), however, has the strongest core offering against non-monetary core attributes with strong appeal against attributes valued by consumers of technology based products and services including '*ease of use*', '*time-saving*' and '*choice variety*'. These three low carbon innovations use technology or apps to improve access to food and private and public forms of mobility (86, 90, 92).

In the bottom centre of the perceptual map cluster 4(d) (circled in green) is a domain specific cluster of food innovations. These are F4 (food pairing apps), F6 (dietary change gamification), F7 (food waste nudges), F8 (urban farming), and F9 (cultured meat). These low carbon innovations have low to moderate appeal against '*ease of use*' and '*choice*' but high appeal against '*healthy*'. Here health relates to a range of both private and public benefits including improved diet (53), improved food

security, and improved public health (48, 112, 131).

5.0 Discussion

5.1 Key findings

Low-carbon innovations appeal to consumers in many different ways beyond their contribution to emission reductions. This review provides novel insights on the wide ranging attributes of low carbon innovations across multiple domains of consumption from mobility and food to homes and energy. It shows that a set of 16 core and non-core attributes are robust and generalisable across consumption domains and the wide variation in context that this implies. This finding in itself is important for it challenges the view that low carbon innovations appeal against a small set of environmental and social benefits which are largely domain specific (203). Although core attributes are fairly homogenous across consumption domains, low carbon innovations within specific domains cluster against a reduced set of non-core attributes. These attributes relate to unique sources of added value over and above incumbent goods and services (5, 8).

Low-carbon innovations are differentiated by non-core attributes but need to perform well on core attributes in order to diffuse more widely. Models from marketing theory including those by Levitt (3) and Kotler and Armstrong (2) emphasise the importance of core attributes in competing effectively with incumbent technologies and practices such as private car use, shopping from supermarkets, and passively using energy without regard to system performance. Accelerating market growth of low carbon innovations requires complementary development and marketing strategies from industry and government. This includes building greater public awareness on the private and public benefits of low carbon innovations.

Low-carbon innovations with strong appeal on core attributes are more compatible with current consumption practices and have stronger potential to move rapidly into the mass market. The transition from car ownership to sharing modes of transport presents a significant challenge not least because it challenges socially acceptable norms of behaviour. In contrast, low carbon innovations such as smart home technologies require only incremental change to current familiar practices such as cooking, or controlling heating and lighting. They also build on the significant developments in the digital economy that enable controllability and manageability of owned assets. In the UK over 90% of adults under the age of 50 have access to the digital economy (they own a smartphone), nearly 100% of all households own a washing machine of some sort (204, 205). This review finds a cluster of smart home innovations which are highly appealing because they offer controllability, and enhanced, real-time automation of household tasks such as heating, lighting, and clothes washing (39). They also have a very strong core offering to consumers. This strong core positioning, combined with their compatibility and familiarity with existing practices suggests homes innovations should have more mass market appeal (1). Although a Mintel survey in 2017 of 2,000 UK consumers found 47% were willing to pay extra for smart home devices (62) currently only between 1-6% of UK households have invested in more energy efficient smart home appliances (46) while the market for low-energy-related smart products like TVs and voice-controlled home assistants has grown rapidly. In the short term governments and industry could offer financial incentives or product leasing and rental agreements to encourage greater adoption. In the longer term a more disruptive strategy would be to shift consumer demand away from buying products towards buying

functionality. This could help overcome the high upfront costs of creating smarter, more energy efficient homes (206).

Novel non-core attributes can drive disruptive change which challenges incumbent firms and mainstream consumer practices. Disruptive innovation is a field of business and management scholarship interested in the transformative potential of novel goods and services for consumers. Its outcome is the dislodging of incumbent firms and interests from entrenched market positions. It builds on the seminal work of Christensen (208) who theorises that incumbents fail to see disruptive threats from innovations which offer a wholly new set of attributes while performing poorly on the core attributes currently valued by mainstream consumers. Low carbon innovations based on the sharing economy model could effectively stimulate disruptive growth in new market segments based on these new set of demands and preferences from consumers (25). To support emission reduction objectives, government, industry and marketing practitioners need to build and support new value propositions around these novel attributes driving innovation towards improved performance on the new dominant adoption criteria.

Sharing-economy innovations in different domains of consumption offer non-core attributes related to social interaction, connectedness, and activity. The appeal of mobility innovations clusters around a reduced set of non-core attributes strongly associated with the sharing economy business models. The sharing economy has experienced significant growth over the last decade, attributed to the fact that it harnesses, and in most cases capitalises on, currently under-utilised physical assets such as private vehicles (207). This review suggests the appeal of low carbon mobility innovations based on the sharing economy model relates not only to their ability to replace the need for car ownership but also to the direct network externalities that accrue as others become connected via the same service (171). This offers potential consumers wider opportunities for social interaction, the ability to connect with like-minded people, and the possibility of becoming more actively involved in 'co-creation' of consumption activity (174).

Digitally-enabled on-demand services have strong potential to outcompete incumbents both in younger consumer segments but increasingly in the mass market as they focus innovation development on continual improvements on core attributes. The digital economy offers opportunity for alternative forms of products and services that challenge incumbent providers who currently maximise on low cost and convenience. There is an emerging cohort of younger consumers referred to as 'Generation Z' who are the first generation to have grown up alongside wide scale access to the digital economy (215). Their rapid socialisation around video gaming, mobile phone apps and web-based technology means they are receptive to web and app-based innovations within the digital and sharing economy. This review identifies a unique cluster of innovations which offer consumers on-demand access to mobility, food and domestic services through smart phones and web-based technology. In addition to having strong potential appeal to this emerging cohort of consumers, these digital innovations are also uniquely positioned to adapt rapidly and competitively within the marketplace. For example, 11th hour food apps such as 'Too Good To Go' (216) use technology platforms that enable them to rapidly improve against core attributes such as ease of use through software improvements in ordering and payment systems, and as technology platforms and digital skills become more widespread.

Low-carbon innovations for managing the supply and use of energy in homes have weak consumer appeal on core attributes and without stronger policy interventions are likely to remain stuck in early-adopting market segments. The way that energy is used and managed in the home is integral to the deep and pervasive changes required within the energy system to mitigate climate change (25). This review included energy innovations that offer consumers a range of technology solutions to managing energy use in their homes. A major finding is that these low carbon innovations have a weak core offering, limited to their potential for saving money. They also have low appeal against other core attributes essential to wider technology acceptance and diffusion (209, 210). Energy innovations are currently positioned to appeal to a specific niche of energy conscious ‘prosumers’ who wish to be more actively involved in managing, generating and trading their household energy. To support growth in this segment, the government needs to re-introduce policy to encourage more active household participation in the energy market. The successful feed in tariff (FIT) scheme introduced by the UK Government in April 2010 offered UK homeowners strong incentives to invest in rooftop solar PV. Resulting adoption contributed towards a new generation of prosumers who were moderately more engaged with their home energy use and needs, along with a more aware and involved relationship with the energy supply system. The FIT scheme closed in March 2019 resulting in a downturn in new solar PV installations (77). Clear signals and actions are now required by the government that continue to challenge the incumbent model of passively using energy whenever and however it is needed in the home. Strategies are required that establish new social norms of behaviour around household energy management.

Clusters of innovations across consumption domains appeal on similar attributes, and are readily linked to specific types of lifestyles. Lifestyles play an important role in shaping consumer behaviour regarding novel low-carbon goods and services (211). Lifestyle not only leads to patterns of behaviour (204), intentions and choices such as where to live and what to eat (212), but also to expressions of self-identity. In marketing lifestyle is used to profile and segment consumers according to their likely purchasing decisions (213, 214). Marketing researchers typically identify constituents of lifestyle in a particular consumption domain such as food or tourism in order to help target relevant goods and services. This review identifies clusters of innovations across consumption domains that similarly appeal against core attributes. For example, a single cluster of mobility and homes innovations support lifestyle change related to health and diet. Government and industry should maximise the benefits from adopting market-segmentation based strategies to target specific lifestyle groups.

5.2 Implications for Government (and policy)

This final section draws on key findings in Section 5.1 to make three additional recommendations for government action.

Recommendation 1 - Support growth of low carbon innovations in the digital and sharing economies by ensuring digital skills are more widespread. The digital economy is growing rapidly in the UK (217). Incentives and educational support are required to bridge the digital divide between more affluent, educated consumers and those with lower skills and motivation. This latter group includes low income rural communities, and employees who have not acquired digital skills through the workplace (218). Interventions could include public skill centres positioned in high footfall public

spaces (such as shopping centres), and providing skills grants for employers, particularly where employees could replace their daily commute with a low carbon alternative.

Recommendation 2 – Support low carbon lifestyle change through funding national and local social marketing campaigns. Social marketing applies the commercial marketing model to products, services and initiatives with public benefits (219). This approach has proved successful in public health where campaigns have targeted behaviour change in smokers, diabetics, and clinically obesity (220). As well as improving outcomes in individuals these campaigns have a wider public benefit. Social marketing interventions have been used by local councils to effect behaviour change. This includes using menu labelling to influence food choices in council run canteens. Integrated national and local campaigns could aid the diffusion of low carbon innovations by building a broad low carbon consumer consciousness throughout the population. This would raise the saliency of low carbon innovations. Priority and provocative topics could include ‘the emissions impact of food’ and ‘the true costs of car ownership’.

Recommendation 3 - Support research and data collection in the early adopter market to identify and understand early adopters, their characteristics and their motivations. Early adopters play a critical role in seeding market growth yet research and practice remains disconnected between private market research and public academic research. Funding streams should be dedicated to aligning professional market research organisations and the academic and non-governmental research communities. Government sponsored social surveys which collect annual data from households should also be directed towards collecting data on low carbon innovations. For example, Understanding Society in the UK is a national, longitudinal survey which interviews over 40,000 households on a repeated annual basis. These surveys need to track low carbon consumption behaviour across a wider range of consumer domains.

6.0 Conclusion

This review addressed the following research questions (1) Do low carbon innovations across four consumer domains share similar attributes? (2) Do low carbon innovations cluster against specific core or non-core attributes?

A directed review of over 170 articles and studies followed by qualitative and quantitative synthesis identified 16 cross cutting attributes that variously appeal within and across four different consumer domains: mobility, food, homes and energy. These domains are important because they all require significant reductions in consumer based CO₂ emissions (221). Seven clusters of low carbon innovations were identified based on their appeal against similar attributes. Three domain specific clusters offered unique added value against non-core attributes. Three cross domain clusters offered added value against core attributes.

Contrary to traditional segmentation approaches focussing on single innovations in single domains, the framing proposed and tested in this review is a segmented approach. It is uniquely based on the shared characteristics and attributes of low carbon innovations. By concentrating on attributes there is an opportunity for government interventions, marketing and communications campaigns to more proactively target specific groups of consumers with low carbon innovations that are also relevant to their needs and expectations.

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Appendix A – Empirical studies based on the Levitt ring model (Table 6)

Table 6 – Core and non-core attributes identified in studies based on the Levitt framing

study	core attributes identified	non-core attributes identified	product/service type (high/ low technology)	product/service
(222)	cleanliness and health	relationship with service providers	low	hotels
(11)	functionality	control, energy efficiency, brand identity	low	washing machines
(6)	ease of use, choice, time-saving	connecting with others	high	instant messaging services
(8)	cleanliness, safety, security, comfort,	environment, societal benefits, sustainability	low	hotels
(4)	cleanliness, safety, security, comfort,	personalisation	low	hotels
(12)	functionality	style, attractiveness	high	mobile phones, laptops
	functionality	style, attractiveness	low	cars
(18)	safety, convenience, cost, infrastructure and services	local environment, entertainment	low	tourist destination
(5)	ease of use, value for money, information	travel experience	low	public transport
(13)	performance	design features	low	cars

Appendix B - Full list of keywords used within the search terms (Tables 7(a) to 7(c))

Table 7(a) - Innovation keywords used in directed review search terms

ref	Innovation keywords	ref	Innovation keywords
T1	car club, car share	F8	urban OR green OR pod AND community AND farm
T2	peer AND to AND peer AND car OR vehicle AND share / p2p AND vehicle OR car AND share	F9	cultured OR lab AND meat
T3	ride AND share	H1	smart AND heat
T4	taxi AND share	H2	smart AND light
T5	mobility AND service OR MaaS	H3	smart AND appliance OR wash OR fridge
T6	electric AND vehicle OR car OR EV	H4	home AND energy AND man OR HEM
T7	electric AND bike OR bicycle OR e-bike	H5	heat AND pumps
T8	autonomous AND vehicle OR car / Self AND driving AND vehicle OR car	H6	prefab AND retrofit
T9	neighbourhood AND vehicle OR car NEV OR ZEV / zero AND emission AND vehicle OR car community AND EV	H7	peer AND to AND peer AND product OR service / p2p AND service OR product
T10	bike AND share	H8	real AND time AND feedback AND energy
T11, T12, T13	telecommuting OR video-conferencing OR telepresence / home AND working / virtual AND meeting	E1	domestic AND electricity AND storage
F1	digital AND hub AND local AND food / online AND farm AND shop / online AND food AND app	E2	peer AND to AND peer AND electricity/p2p AND electricity
F2	meal AND kit OR box	E3	electric AND vehicle OR car AND grid
F3	11 th AND hour AND app	E4	time AND use AND price AND elec
F4	food AND pairing OR matching	E5	demand AND response AND elec
F5	food OR community AND share	E6	energy AND service AND Co / ESC
F6	gamification AND diet OR food	E7	third AND party AND finance AND elec
F7	nudge AND food OR waste		

Table 7(b) - Attribute keywords used in directed review search terms

main keyword	attribute keywords
cost-saving	cost OR price OR cheap
time-saving	time OR convenient
healthy	health OR wellbeing OR comfort
safe and secure	safe OR secure
ease of use	easy OR accessible OR convenient OR hassle
choice variety	choice OR select OR flexibility
environmental benefit	environment AND OR CO ₂ emissions AND OR pollution AND OR low carbon AND OR waste AND OR efficient
social benefit	community AND OR local AND OR society
relational	relationship AND OR interaction AND OR share AND OR friendship AND OR sociable
active involvement	involvement AND provision
pay-per-use	pay AND use AND OR subscription
service-based	service OR own AND OR third-party AND OR maintain
multiple use	use AND range AND OR function
control	control OR influence OR manage
autonomy	autonomy OR independent OR agency
identity signal	identity OR image OR esteem

Table 7(c) - Innovation examples used in directed review search terms

ref	examples	F7	-
T1	Zipcar, City Car Club, Co-Wheels	F8	Food from the Sky (UK), Gotham Greens (US)
T2	Liftshare	F9	Mosa Meat, Meatable
T3	Bla Bla Car, Liftshare	H1	Samsung Smart Fridge,
T4	Lyft Line, UberPool	H2	Philips Hue
T5	Whim (Helsinki)	H3	Samsung Smart Fridge, Bosch Washing Machine with Home Connect
T6	Tesla (top range), Nissan Leaf (mid range), Renault Zoe (bottom range)	H4	CarbonTRACK
T7	Raleigh Redux, GenZe 200	H5	-
T8	Waymo, Uber, Tesla Model S Autopilot	H6	Energiesriong
T9	Renault Twizy, BugE	H7	Streetbank, Freecycle, eBay, Gumtree
T10	Santander Cycles (London), Ofo (Beijing)	H8	-
T11	Cisco, Polycom	E1	Tesla PowerWall
T12		E2	Piclo, Vandenbron, Power Ledger
T13		E3	Nissan Leaf - Ovo
F1	Heartier, Farmdrop, Open Food Network UK	E4	-
F2	Hello Fresh, Gousto	E5	-
F3	FoodCloud, NoFoodWasted	E6	Vital Energi
F4	-	E7	-
F5	Olio, Hubub, Share your Meal, TooGoodToGo	E8	Solarplicity
F6	FIT game (US)		

Appendix C Full description of low carbon innovations (Tables 8(a) to 8(d))

The 38 low carbon innovations included in this study are more fully explained in Tables 8(a) to 8(d) below. These tables describe each low carbon innovation in detail. Column (a) highlights the incumbent technology or behaviour which needs to be displaced for significant CO₂ reductions to occur within this domain. In mobility the dominant consumer behaviour is private car use which accounts for over 75% of UK private vehicle kms (223). In the food sector the dominant consumer behaviour is big food shopping from large scale food retailers (and associated waste) which accounts for 95% of grocery expenditure (224). In the homes sector and energy sector the dominant consumer behaviour is inefficient and passive energy use and waste. Columns (b) and (c) distinguish between low carbon innovations according to alternative models of provision. These are ownership (own) versus service economy (se) and the centralised retailing model (cr) versus and sharing economy (se) (see also Section 3.1). Where low carbon innovations offer multiple modes of provision this is indicated.

Table 8(a) - mobility innovations used in this study

ref	Low carbon innovation	description	(a)	(b)	(c)
T1	car clubs or car sharing	allow members to book, pay for, and use vehicles belonging to the club which may be parked in specific places or be locatable through an app or website.	owning or using a private car, commuting or travelling for work	sb	se
T2	p2p car sharing	enable users who are car owners to lend their cars on a temporary basis to other users in exchange for payment.		sb	se
T3	ride sharing	connect passengers wanting to make a specific journey with drivers making the same journey who are willing to give them a lift in exchange for payment or for free.		sb	se
T4	shared taxi (or taxibus)	can be called and used by multiple passengers with similar routes who each specify their start point and destination using an app.		sb	se
T5	mobility as a service (MaaS)	an app or website which integrates planning, booking and paying for journeys on a range of public, shared and private transport modes.		sb	cr
T6	EVs (EVs)	powered by on-board batteries which are recharged by plugging the car in at designated charging points. Can be owned or shared as part of car club or car sharing		own /sb	cr /se
T7	e-bikes	electric motor and battery for assisting with pedalling or for powering the bicycle up to limited speeds. Can be owned or shared as part of MaaS		own /sb	cr /se
T8	autonomous vehicles (AVs)	fully autonomous vehicles in which no driver or back-up driver required. AVs can be owned or shared as part of MaaS.		own /sb	cr /se
T9	neighbourhood EVs (NEVs)	low speed battery EVs (similar to a golf buggy)		own /sb	cr /se
T10	bike-sharing	a service in which bicycles are made available for shared use to individuals on a short term basis for a price		sb	se
T11	telecommuting	the elimination or partial elimination of a commute trip by working from home		own	cr
T12	videoconferencing and virtual meetings	a conference or meeting between two or more participants at different sites by using computer networks to transmit audio and video data		sb	cr
T13	telepresence and virtual reality	systems which present interactive video and audio between locations with near life like audio quality and with near life size video images.		sb	cr

note (a) main incumbent/ behaviour change; (b) service-based provision (sb) or ownership (own); (c) centralised retail (cr) or sharing economy (se)

Table 8(b) - food innovations used in this study

ref	Low carbon innovation	description	(a)	(b)	(c)
F1	digital hubs for local food	online versions of farmers markets in the form of a website or app through which people can buy a range of food products for delivery from different local producers.	buying from large food retailers, wasting food (farm to plate)	own	cr
F2	meal kits	boxes of pre-portioned ingredients for specific recipes delivered to households for preparing freshly cooked meals at home.		own	cr
F3	11 th hour apps	enable cafes, restaurants or supermarkets to advertise unsold meals or surplus fresh food to consumers at significantly reduced prices		sb	se
F4	food pairing apps	provide recipe suggestions for making use of ingredients left in fridges or cupboards, with particular emphasis on vegetarian food.		sb	cr
F5	food sharing	connects users to excess home-grown vegetables, food nearing its sell by date in local shops and any unwanted food in households		own	se
F6	dietary change gamification	behaviour change games that encourage a transition from high meat diets		sb	cr
F7	food waste reduction nudges	providing a choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentive		sb	cr
F8	urban farming	using greenhouse technology (stacking greenhouses on top of each other) which situates the growing of food within buildings (homes and workplaces)		own	cr
F9	cultured meat	animal meat that is grown using a bioreactor instead of an animal		own	cr

note (a) main incumbent/ behaviour change; (b) service-based provision (sb) or ownership (own); (c) centralised retail (cr) or sharing economy (se)

Table 8(c) - homes innovations used in this study

ref	Low carbon innovation	description	(a)	(b)	(c)
H1	smart heating systems	can learn and automate heating schedules while also enabling household members to control the heating through an app or website even when they are not at home	not actively managing energy (resources)	own	cr
H2	smart lighting	enable household members to control the brightness and hues of bulbs using an app or voice commands.		own	cr
H3	smart appliances	include washing machines and fridges are connected to the internet and can be controlled by household members through an app or website.		own	cr
H4	home energy management systems (HEMs)	technology platform which relays multiple information on home energy use and occupancy which allows the user to monitor energy usage, production and manually control or automate energy use		own	cr
H5	heat pumps	storage solutions to match energy supply to heating and cooling demand, efficient transfer of heat from point of production / storage to point of use.		own	cr
H6	prefab retrofits	non-intrusive retrofit fitted externally, completed within one week without residents having to move out, off-site fabrication with quality control and standardised volume production		own	cr
H7	p2p products and services	individuals or households exchanging products or other material goods through an online marketplace		own	se
H8	real-time feedback on aggregated loads	interactive smart meters in every household and small business site improve grid responsive and interactivity + disaggregation algorithms to appliance level (or activities) help inform domestic energy management		sb	cr

note (a) main incumbent/ behaviour change; (b) service-based provision (sb) or ownership (own); (c) centralised retail (cr) or sharing economy (se)

Table 8(d) - energy innovations used in this study

ref	Low carbon innovation	description	(a)	(b)	(c)
E1	domestic electricity generation with storage	households can store surplus electricity they generate for later consumption using a battery system.	buying energy from centralised utilities or not actively managing energy	own	cr
E2	p2p electricity trading	households can buy and sell electricity they've generated at home directly with other households through an online platform.		own	se
E3	electric vehicle to grid	energy companies can control when to recharge or discharge batteries in EVs which are plugged in, subject to pre-agreed terms with the vehicle owners.		own	cr
E4	time of use pricing	exposing retail consumers to (highly variable) marginal costs of supply (especially very high peak prices) as a financial incentive for load shifting		own	cr
E5	demand response	remote (utility) or automated (software) management of loads (typically large users) in response to price signals or supply shortages		own	cr
E6	energy service companies	third-party management of energy consumption on a service- or performance-contract basis to incentivise energy-saving investments		sb	cr
E7	third-party financing	third-party financing of generation assets (esp. rooftop PV) - e.g., roof leasing, property tax adjustments (PACE), mortgages (esp. if building integrated)		sb	cr
E8	community energy	a community-led project or process to meet its own energy requirements through decentralized generation (electricity, heating) and/or demand-side efficiency		sb	se

note (a) main incumbent/ behaviour change; (b) service-based provision (sb) or ownership (own); (c) centralised retail (cr) or sharing economy

Appendix D – Identification of cross domain over-lapping attribute themes (Tables 9(a) to 9(b))

The synthesis of qualitative data draws on a thematic analysis in Pettifor, Wilson (29). This study used structured elicitation methods, interviewing over 60 people living in a representative city. In these interviews respondents were encouraged to discuss what they considered was the widespread appeal of low carbon innovations. Similar to this review, innovations represented four key domains of mobility, food, homes and energy. Table 9 illustrates how the main themes elicited from these interviews (Table 9 columns (a) and (b)) have informed the identification of over-lapping themes in this review (Table 9 columns (c) and (d)).

Table 9(a) – Source of overlapping themes identified in this review (core attributes)

	Pettifor, Wilson (29)		This review	
Ref	main themes identified from interviews (c)	sub-themes identified from interviews (b)	attributes identified from directed review (c)	main themes from qualitative findings (d)
C1	offers clear monetary benefits	'cost-saving', 'low price', 'low running costs', 'money saving'	cost-saving	'financial savings and lower costs', 'value for money'
C4	is easy to use, reduces hassle or is more convenient	'inclusive', 'accessible', 'low complexity', 'low difficulty', 'familiar and accessible platform' (smart app on a phone)	ease of use	'convenience', 'accessibility', 'low hassle', 'flexibility', 'on demand', 'simplicity', 'easy to understand'
C6	is easy to use, reduces hassle or is more convenient			
C6	is widely accessible			
C17	requires no prior knowledge			
C19	improves accessibility through use of smartphone			
C22	positively supports healthy living	'safe and secure', 'builds safer communities'	safe and secure	'increased food security', 'safer food', 'personal and family security' 'avoid energy blackouts'
		'reduced stress', 'improved personal health & wellbeing', 'increased personal comfort'	healthy	'improved emotional and physical fitness', 'improved quality of life', 'healthier living and working environments', 'improved diet and nutrition'
C5	is more time efficient	'not time consuming', 'saves time', 'efficient use of time'	time-saving	'reduces time', 'frees up time', 'more productive use of time'
C18	allows users to choose alternative forms of good	'flexible choice', 'personalised choice', 'more choice'	choice variety	'choice of use', 'choice of products', 'choice of suppliers'

Table 9(b) – Source of overlapping themes identified in this review (non-core attributes)

	Pettifor, Wilson (29)		This review	
C2	reduces impact on the environment	'good for the environment', 'reduces waste', 'reduces CO ₂ emissions', 'maximises use of resources' (stuff space), 'more energy efficient'	environmental benefit	'lowers CO ₂ emissions and avoids pollution', 'avoids waste', 'builds more sustainable marketplaces and greener cities', 'reduces consumption'
C15	maximises use of resources			
C7	directly benefits local economy or community	'supports local economy', 'improves/supports local business (profit margins)', 'keep things local', 'creates local jobs', 'source local goods and services', 'collective benefits'	social benefit	'inclusive', 'help and support others', 'educate', 'enhanced local biodiversity and utilisation of space', 'builds communities', 'widespread common good', 'provides benefits to others'
C23	benefits a collective, wider population			
C27	actively builds relationships with other users	'sociable', 'shareable', 'friendships', 'links family and friends',	relational	'integration into a community, 'strengthens relationships, 'enhances or creates social networks'
C14	encourages mutual interactions or builds friendships	'mutual exchange is encouraged', 'mutual benefits'		'co-creation', 'sharing with others', 'self-reward framework', 'proactive management'
C20	involves or strengthens interactions within a community	'promotes community', 'enhances interactions with community',	active involvement	'co-creation', 'sharing with others', 'self-reward framework', 'proactive management'
C25	connects people with producers	'connects people with local services'		
C32	involves users in creating or providing good or service	'involves users in creating or providing good or service'		
C1	offers clear monetary benefits	'low upfront costs', 'no upfront costs'	pay-per-use	'usage-based consumption', 'removal of upfront costs', 'access without ownership'
C16	reduces dependence on others	'reduces or negates the need for owning a good', 'hands over responsibility to third-party'	service-based	'third-party management', 'flexible usage'
C18	allows users to choose alternative forms of good	'allows users to choose alternative forms of the good or service to suit different needs or contexts'	multiple use	'additional services', 'access to multiple services'
C9	enables or improves controllability	'improved personal control', 'improved technology control', 'control of the service', 'of the resource', 'of the cost, 'improved organisation of day to day life', 'improved clarity'	control	improved monitoring', 'improved management', 'automation'
C16	reduces dependence on others	'increased independence', 'increased agency'	autonomy	'independence', 'alternatives to major systems of centralised provision'
C26	enhances separation from others			
C11	enhances personal image and self-identity	'supports or enhances desirable aspects of end-user's individual or social identity'	identity signal	'collective identity', 'environmental symbolism'

Appendix E – Detailed scorings of clusters against attributes (Tables 10(a) to 10(b))

Table 10(a) – the appeal of clusters 1 to 3 against non-core attributes

type	attribute	cluster 1							cluster 2				cluster 3							
		T1	T2	T3	T4	T8	T10	H7	H1	H2	H3	H4	E1	E2	E3	E4	E5	E6	E7	E8
core	cost-saving																			
	ease of use																			
	safe and secure																			
	healthy																			
	time-saving																			
	choice																			
non-core	env. benefits																			
	social benefit																			
	relational																			
	active involvement																			
	multiple use																			
	control																			
	pay-per-use																			
	service-based																			
	autonomy																			
	identity signal																			

Key to attribute strength

	non-relevant/no appeal
	low appeal
	modest appeal
	high appeal

Key to innovations in each cluster

cluster 1		cluster 2		cluster 3	
T1	car clubs	H1	smart heating systems	E1	domestic electricity + storage
T2	p2p car share	H2	smart lighting	E2	p2p electricity trading
T3	ride share	H3	smart appliances	E3	V2G
T4	shared taxi	H4	HEMs	E4	time of use pricing
T8	AVs			E5	demand response
T10	bike-share			E6	energy service companies
H7	p2p products			E7	third-party financing

note (blue=mobility, green=food, red=homes, blue=energy)

Table 10(b) – The appeal of clusters 4(a) to 4(d) against core attributes

type	attribute	cluster 4(a)						cluster 4(b)					cluster 4(c)			cluster 4(d)					
		T6	F3	F5	H5	H6	H8	T7	T9	T11	T12	T13	F1	F2	T5	F3	F4	F6	F7	F8	F9
core	cost-saving																				
	ease of use																				
	safe and secure																				
	healthy																				
	time-saving																				
	choice																				
non-core	env. benefits																				
	social benefit																				

Key to attribute strength

	non-relevant/no appeal
	low appeal
	modest appeal
	high appeal

Key to innovations in each cluster

Cluster 4a		Cluster 4b		Cluster 4c		Cluster 4d	
T6	EVs	T7	e-bikes	F1	digital hubs food	F4	food pairing apps
F3	11th hour apps	T9	NEVs	F2	meal kits	F6	dietary change gamification
F5	food sharing	T11	telecommuting	T5	MaaS	F7	food waste nudges
H5	heat pumps	T12	video-conferencing			F8	urban farming
H6	prefab retrofits	T13	telepresence			F9	cultured meat
H8	real-time feedback						

note (blue=mobility, green=food, red=homes, blue=energy)

List of References

1. Rogers EM. Diffusion of Innovations. New York: Free Press; 2003.
2. Kotler P, Armstrong G. Principles of Marketing. 10th edition ed. Upper Saddle River, NJ: Pearson Education; 2004.
3. Levitt T. Marketing success through differentiation--of anything. Harvard Business Review. 1980;58(1):83-91.
4. Slevitch L, Oh H. Asymmetric relationship between attribute performance and customer satisfaction: A new perspective. International Journal of Hospitality Management. 2010;29(4):559-69.
5. Brechan I. The different effect of primary and secondary product attributes on customer satisfaction. Journal of Economic Psychology. 2006;27(3):441-58.
6. Lee K, Khan S, Mirchandani D. Hierarchical effects of product attributes on actualized innovativeness in the context of high-tech products. Journal of Business Research. 2013;66(12):2634-41.
7. Leviit T. The Marketing Imagination. New York, NY: Free Press; 1983.
8. Slevitch L, Mathe K, Karpova E, Scott-Halsell S. "Green" attributes and customer satisfaction: optimisation of resource allocation and performance. International Journal of Contemporary Hospitality Management. 2013;26(6):802-22.
9. Yen C-LA, Tang C-HH. The effects of hotel attribute performance on electronic word-of-mouth (eWOM) behaviors. International Journal of Hospitality Management. 2019;76:9-18.
10. Schuitema G, Anable J, Skippon S, Kinnear N. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. Transportation Research Part A: Policy and Practice. 2013;48(0):39-49.
11. Wang Y, Lu X, Tan Y. Impact of product attributes on customer satisfaction: An analysis of online reviews for washing machines. Electronic Commerce Research and Applications. 2018;29:1-11.
12. Chitturi R, Raghunathan R, Mahajan V. Delight by Design: The Role of Hedonic Versus Utilitarian Benefits. Journal of Marketing. 2008;72(3):48-63.
13. Dhar R, Wertenbroch K. Consumer Choice Between Hedonic and Utilitarian Goods. Journal of Marketing Research (JMR). 2000;37(1):60-71.
14. Axsen J, Kurani KS. Interpersonal influence within car buyers' social networks: applying five perspectives to plug-in hybrid vehicle drivers. Environment and Planning A. 2012;44(5):1047-65.
15. Kano N, Nobuhiku S, Takahashi F, Tsuji S. Attractive quality and must-be quality. Journal of the Japanese Society for Quality Control (in Japanese). 1984;14(2):39-48.
16. Carplus. Annual survey of car clubs in England and Wales. Department for Transport; 2016.
17. Achtnicht M, Bühler G, Hermeling C. The impact of fuel availability on demand for alternative-fuel vehicles. Transportation Research Part D: Transport and Environment. 2012;17(3):262-9.
18. Huang R, Sarigöllü E. Assessing satisfaction with core and secondary attributes. Journal of Business Research. 2008;61(9):942-9.
19. Sovacool BK, Axsen J. Functional, symbolic and societal frames for automobility: Implications for sustainability transitions. Transportation Research Part A: Policy and Practice. 2018;118:730-46.
20. Botsman R, Rogers R. What's Mine is Yours, How collaborative consumption is changing the way we live. London: Collins; 2010.
21. Gargiulo E, Giannantonio R, Guercio E, Borean C, Zenezini G. Dynamic Ride Sharing Service: Are Users Ready to Adopt it? Procedia Manufacturing. 2015;3(Supplement C):777-84.
22. Wilhelms M-P, Henkel S, Falk T. To earn is not enough: A means-end analysis to uncover peer-providers' participation motives in peer-to-peer carsharing. Technological Forecasting and Social Change. 2017;125:38-47.
23. Michelini L, Principato L, Iasevoli G. Understanding Food Sharing Models to Tackle Sustainability Challenges. Ecological Economics. 2018;145(Supplement C):205-17.

24. Hsieh H-F, Shannon SE. Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*. 2005;15(9):1277-88.
25. Wilson C. Disruptive low-carbon innovations. *Energy Research & Social Science*. 2018;37:216-23.
26. Wilson C, Pettifor H, Cassar E, Kerr L, Wilson M. The potential contribution of disruptive low-carbon innovations to 1.5 °C climate mitigation. *Energy Efficiency*. 2018.
27. Frenken K, Schor J. Putting the sharing economy into perspective. *Environmental Innovation and Societal Transitions*. 2017;23:3-10.
28. Benkler Y. Sharing Nicely: On Shareable Goods and the Emergence of Sharing as a Modality of Economic Production. *The Yale Law Journal*. 2004;114:273.
29. Pettifor H, Wilson C, Bogelein S, Cassar E, Kerr L, Wilson M. Are low carbon innovations appealing? A typology of functional, symbolic, private and public attributes. *Energy Research & Social Science* [Accepted for publication]. 2020.
30. Kruskal JB. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika*. 1964;29(1):1-27.
31. Kruskal JB, Wish M. *Multidimensional Scaling*. Thousand Oaks, California 1978. Available from: <https://methods.sagepub.com/book/multidimensional-scaling>.
32. Sühlsen K, Hisschemöller M. Lobbying the 'Energiewende'. Assessing the effectiveness of strategies to promote the renewable energy business in Germany. *Energy Policy*. 2014;69:316-25.
33. StataCorp. *Stata Statistical Software: Release 16*. College Station, TX:StataCorp LLC 2019 [
34. Arbib J, Seba T. Rethinking transportation 2020-2030: the disruption of transportation and the collapse of the internal combustion vehicle and oil industries. *RethinkX*; 2017.
35. Ashdown BG, Bjornstad DJ, Boudreau G, Lapsa MV, Schexnayder S, Shumpert B, et al. Heat pump water technology: experiences of residential consumers and utilities. ORNL 2004.
36. Axsen J, Goldberg S, Bailey J. How might potential future plug-in electric vehicle buyers differ from current "Pioneer" owners? *Transportation Research Part D: Transport and Environment*. 2016;47:357-70.
37. Ayre J. Neighborhood electric vehicles gaining in popularity. *Clean Technica*. 2015.
38. Bardhi F, Eckhardt GM. Access-Based Consumption: The Case of Car Sharing. *Journal of Consumer Research*. 2012;39(4):881-98.
39. Carbon Track. 2019 [Available from: <https://carbontrack.com.au/blog/what-is-a-home-energy-management-system/>].
40. Caulfield B. Does it pay to work from home? Examining the factors influencing working from home in the Greater Dublin Area. *Case Studies on Transport Policy*. 2015;3(2):206-14.
41. CBS News. Burger grown from cow stem cells in laboratory put to taste test in London 2013 [Available from: <https://www.cbsnews.com/news/burger-grown-from-cow-stem-cells-in-laboratory-put-to-taste-test-in-london/>].
42. Chew I, Karunatilaka D, Tan CP, Kalavally V. Smart lighting: The way forward? Reviewing the past to shape the future. *Energy and Buildings*. 2017;149(Supplement C):180-91.
43. Coldwell Banker, CNET. Americans ready for the smart home - results of the Coldwell Banker and CNET smart home survey. 2015.
44. de Boer J, Schösler H, Aiking H. Towards a reduced meat diet: Mindset and motivation of young vegetarians, low, medium and high meat-eaters. *Appetite*. 2017;113:387-97.
45. Despommier D. Farming up the city: the rise of urban vertical farms. *Trends in Biotechnology*. 2013;31(7):388-9.
46. Energi Sprong UK. *Desirable, Warm, Affordable Homes for Life 2017* [Available from: <https://www.energiesprong.uk/>].
47. Geske J, Schumann D. Willing to participate in vehicle-to-grid (V2G)? Why not! *Energy Policy*. 2018;120:392-401.
48. Grebitus C, Printezis I, Printezis A. Relationship between Consumer Behavior and Success of Urban Agriculture. *Ecological Economics*. 2017;136:189-200.

49. Halden D. Review of demand responsive transport in Scotland. 2006.
50. Hamari J, Sjöklint M, Ukkonen A. The sharing economy: Why people participate in collaborative consumption. *Journal of the Association for Information Science & Technology*. 2016;67(9):2047-59.
51. Huey-Yeh L, Mei-Hsiang W, Min-Jhen W. A STUDY OF AIRBNB USE BEHAVIOR IN THE SHARING ECONOMY. *International Journal of Organizational Innovation*. 2017;10(1):38-47.
52. Jessoe K, Rapson D. Knowledge Is (Less) Power: Experimental Evidence from Residential Energy Use. *American Economic Review*. 2014;104(4):1417-38.
53. Johnson D, Deterding S, Kuhn K-A, Staneva A, Stoyanov S, Hides L. Gamification for health and wellbeing: A systematic review of the literature. *Internet Interventions*. 2016;6:89-106.
54. Koh H. A new app to save food at the 11th hour: Eco-Business 2016 [Available from: <https://www.eco-business.com/news/a-new-app-to-save-food-at-the-11th-hour/>].
55. KPMG. Reimagine Places: Mobility as a Service. 2017.
56. Laker L. Rise of the e-bike: how going electric could revolutionise your ride 2017 [Available from: <https://www.theguardian.com/lifeandstyle/2017/sep/16/rise-of-the-ebike-how-going-electric-could-revolutionise-your-ride>].
57. Leister EH, Vairo N, Sims D, Bopp M. Understanding bike share reach, use, access and function: An exploratory study. *Sustainable Cities and Society*. 2018;43:191-6.
58. Lindeblad PA, Voytenko Y, Mont O, Arnfalk P. Organisational effects of virtual meetings. *Journal of Cleaner Production*. 2016;123:113-23.
59. Louis J-N, Calo A, Leiviskä K, Pongrácz E. Environmental Impacts and Benefits of Smart Home Automation: Life Cycle Assessment of Home Energy Management System. *IFAC-PapersOnLine*. 2015;48(1):880-5.
60. Lovett G. Is urban farming only for rich hipsters? 2016 [Available from: <https://www.theguardian.com/sustainable-business/2016/feb/15/urban-farming-rich-hipsters-food-affordability-inequality>].
61. Mintel. Hybrid and electric cars UK. Mintel; 2016.
62. Mintel. The connected home. 2017.
63. Möhlmann M. Collaborative consumption: determinants of satisfaction and the likelihood of using a sharing economy option again. *Journal of Consumer Behaviour*. 2015;14(3):193-207.
64. Nishio K-I, Mukai T. Behavior changes in use of home appliances effected by time-of-use tariff - Bias-adjusted questionnaire data analysis based on propensity score. *Journal of Environmental Engineering (Transactions of AIJ)*. 2016;81(729):1025-34.
65. Perchard E. New app hoping to revolutionise restaurants' treatment of surplus food that is too good to go: Resource; 2019 [Available from: <https://resource.co/article/new-app-hoping-revolutionise-restaurants-treatment-surplus-food-too-good-go-11292>].
66. Prettenthaler FE, Steininger KW. From ownership to service use lifestyle: the potential of car sharing. *Ecological Economics*. 1999;28(3):443-53.
67. Prieto M, Baltas G, Stan V. Car sharing adoption intention in urban areas: What are the key sociodemographic drivers? *Transportation Research Part A: Policy and Practice*. 2017;101:218-27.
68. Rayle L, Dai D, Chan N, Cervero R, Shaheen S. Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. *Transport Policy*. 2016;45(Supplement C):168-78.
69. Roby H. Understanding the development of business travel policies: Reducing business travel, motivations and barriers. *Transportation Research Part A: Policy and Practice*. 2014;69:20-35.
70. Saenz Z. Business travel declines with telepresence conference calls: The Singularity Hub; 2009 [Available from: <https://singularityhub.com/2009/10/02/business-travel-declines-with-telepresence-conference-calls/>].
71. Sáez-Martí M, Zenou Y. Cultural transmission and discrimination. *Journal of Urban Economics*. 2012;72(2-3):137-46.

72. Salkin PE, Grady G, Mueller N, Herendeen S. Government "green" requirements and "LEEDigitation". 40 Real Estate L.J.; 2012.
73. Satre-Meloy A, Diakonova M, Grünwald P. Daily life and demand: an analysis of intra-day variations in residential electricity consumption with time-use data. Energy Efficiency. 2019.
74. The Economist. The rise of the sharing economy 2013 [Available from: <https://www.economist.com/news/leaders/21573104-internet-everything-hire-rise-sharing-economy>].
75. The Greenage. The advantages and disadvantages of the smart grid system 2017 [Available from: <https://www.thegreenage.co.uk/tech/consumers-and-the-smart-grid/>].
76. Yoon T, Cherry CR, Jones LR. One-way and round-trip carsharing: A stated preference experiment in Beijing. Transportation Research Part D: Transport and Environment. 2017;53:102-14.
77. The Energy Saving Trust. the heat is on: heat pump field trials phase 2. 2017.
78. Wainstein ME, Bumpus AG. Business models as drivers of the low carbon power system transition: a multi-level perspective. Journal of Cleaner Production. 2016;126:572-85.
79. Askew K. Competition in meal kits heats up as Unilever enters fray: Food Navigator; 2017 [Available from: <https://www.foodnavigator.com/Article/2017/10/20/Competition-in-meal-kits-heats-up-as-Unilever-enters-fray>].
80. Borggren C, Moberg Å, Räsänen M, Finnveden G. Business meetings at a distance – decreasing greenhouse gas emissions and cumulative energy demand? Journal of Cleaner Production. 2013;41:126-39.
81. Boxall H. Tesco begins rollout of national food waste scheme: Resource; 2016 [Available from: <https://resource.co/article/tesco-begins-rollout-national-food-waste-scheme-10947>].
82. Buchanan K, Russo R, Anderson B. The question of energy reduction: The problem(s) with feedback. Energy Policy. 2015;77(Supplement C):89-96.
83. Burkhardt JE, Millard-Ball A. Who is Attracted to Carsharing? Transportation Research Record. 2006;1986(1):98-105.
84. Caulfield B. Estimating the environmental benefits of ride-sharing: A case study of Dublin. Transportation Research Part D: Transport and Environment. 2009;14(7):527-31.
85. Chen TD, Kockelman KM. Carsharing's life-cycle impacts on energy use and greenhouse gas emissions. Transportation Research Part D: Transport and Environment. 2016;47:276-84.
86. Cleveland DA, Müller NM, Tranovich AC, Mazaroli DN, Hinson K. Local food hubs for alternative food systems: A case study from Santa Barbara County, California. Journal of Rural Studies. 2014;35:26-36.
87. Crist R. Smart bulbs vs. smart switches: the pros and cons of connected lighting: Cnet.; 2015 [Available from: <https://www.cnet.com/news/microsoft-thinks-a-dual-screen-android-phone-can-take-on-apple-and-samsung/>].
88. Fox K. FoodCloud: new app proves a nourishing idea for wasted food: The Observer; 2016 [Available from: <https://www.theguardian.com/environment/2016/dec/04/new-app-proves-a-nourishing-idea-for-wasted-food-foodcloud>].
89. Furuhashi M, Dessouky M, Ordóñez F, Brunet M-E, Wang X, Koenig S. Ridesharing: The state-of-the-art and future directions. Transportation Research Part B: Methodological. 2013;57(Supplement C):28-46.
90. Hertz FD, Halkier B. Meal box schemes a convenient way to avoid convenience food? Uses and understandings of meal box schemes among Danish consumers. Appetite. 2017;114:232-9.
91. Icontrol Networks. State of the smart home report. Icontrol Networks; 2015.
92. Kamargianni M, Li W, Matyas M, Schäfer A. A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia. 2016;14:3294-303.
93. Mintel. Amazon trials farmers market direct delivery. USA: Mintel; 2015.
94. Priya Uteng T, Julsrud TE, George C. The role of life events and context in type of car share uptake: Comparing users of peer-to-peer and cooperative programs in Oslo, Norway. Transportation Research Part D: Transport and Environment. 2019.

95. Schaefer T. Exploring carsharing usage motives: A hierarchical means-end chain analysis. *Transportation Research Part A: Policy and Practice*. 2013;47:69-77.
96. Shaheen S, Sperling D, Wagner C. Carsharing in Europe and North America: Past, Present, and Future. *Transportation Quarterly*. 1998;52(3):35-52.
97. Shin J, Park Y, Lee D. Who will be smart home users? An analysis of adoption and diffusion of smart homes. *Technological Forecasting and Social Change*. 2018;134:246-53.
98. Si H, Shi J-g, Wu G, Chen J, Zhao X. Mapping the bike sharing research published from 2010 to 2018: A scientometric review. *Journal of Cleaner Production*. 2019;213:415-27.
99. Stragier J, Hauttekeete L, De Marez L. "Introducing smart grids in residential contexts: consumers' perception of smart household appliances", *Innovative technologies for an efficient and reliable electricity supply (CITRES)*. IEEE Conference; Waltham, MA: IEE; 2010. p. 135-2.
100. von Kameke C, Fischer D. Preventing household food waste via nudging: An exploration of consumer perceptions. *Journal of Cleaner Production*. 2018;184:32-40.
101. Winslott Hiselius L, Svensson A. Could the increased use of e-bikes (pedelecs) in Sweden contribute to a more sustainable transport system? *The 9th International Conference "Environmental Engineering"*; Vilnius, Lithuania: VGTU Press; 2014.
102. Wolf A, Seebauer S. Technology adoption of electric bicycles: A survey among early adopters. *Transportation Research Part A: Policy and Practice*. 2014;69(Supplement C):196-211.
103. YouGov. The dawn of the connected home. Resources, White papers; 2018.
104. Larbey R. Cities for food systems innovation and green jobs. DG Research & Innovation; 2017.
105. Scottow Enterprise. A prefab approach for a Passivhaus deep retrofit: Scottow Enterprise Park 2016 [Available from: <https://scottowenterprise.com/news/a-prefab-approach-for-a-passivhaus-deep-retrofit/>].
106. Professional Engineering Technology. Electric Gem drives into Europe. *Professional Engineering*. 2005;18(16):49-.
107. Balta-Ozkan N, Davidson R, Bicket M, Whitmarsh L. Social barriers to the adoption of smart homes. *Energy Policy*. 2013;63:363-74.
108. Daws R. Research: Nest reveals consumer feelings about IoT 2016 [Available from: <https://www.iottechnews.com/news/2016/may/04/research-nest-reveals-consumer-feelings-about-iot/>].
109. Farley M. Why the consumer internet of things is stalling: CIO Network; 2016 [Available from: <https://www.forbes.com/sites/ciocentral/2016/09/13/why-the-consumer-internet-of-things-is-stalling/#66c3bf9841f1>].
110. Khajenasiri I, Estebasari A, Verhelst M, Gielen G. A Review on Internet of Things Solutions for Intelligent Energy Control in Buildings for Smart City Applications. *Energy Procedia*. 2017;111:770-9.
111. KMPG Car Group. Self driving cars: the next revolution. 2012.
112. Larsen K, Gilliland J. A farmers' market in a food desert: Evaluating impacts on the price and availability of healthy food. *Health & Place*. 2009;15(4):1158-62.
113. Mintel. Asda's wonky veg box continues war on food waste. UK: Mintel; 2015.
114. Naber R, Raven R, Kouw M, Dassen T. Scaling up sustainable energy innovations. *Energy Policy*. 2017;110:342-54.
115. Smithers R. Co-Op to see food past its 'best before' date in a bid to cut waste: *The Guardian*; 2017 [Available from: <https://www.theguardian.com/environment/2017/dec/04/retailer-to-sell-food-past-its-best-before-date-in-bid-to-cut-waste>].
116. Verbeke W, Marcu A, Rutsaert P, Gaspar R, Seibt B, Fletcher D, et al. 'Would you eat cultured meat?': Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom. *Meat Science*. 2015;102:49-58.
117. Aschemann-Witzel J, Jensen JH, Jensen MH, Kulikovskaja V. Consumer behaviour towards price-reduced suboptimal foods in the supermarket and the relation to food waste in households. *Appetite*. 2017;116:246-58.

118. Cairns S, Harmer C. The emission impacts of car clubs in London. London: Transport Research Laboratory; 2012.
119. Chuck C, Fernandes SA, Hyers LL. Awakening to the politics of food: Politicized diet as social identity. *Appetite*. 2016;107:425-36.
120. De Groote M, Volt J, Bean F. Smart Buildings Decoded. UK: Buildings Performance Institute (BPIE); 2017.
121. Feldmann C, Hamm U. Consumers' perceptions and preferences for local food: A review. *Food Quality and Preference*. 2015;40, Part A:152-64.
122. Goodwin JN, Shoulders CW. The future of meat: A qualitative analysis of cultured meat media coverage. *Meat Science*. 2013;95(3):445-50.
123. Graça J, Oliveira A, Calheiros MM. Meat, beyond the plate. Data-driven hypotheses for understanding consumer willingness to adopt a more plant-based diet. *Appetite*. 2015;90:80-90.
124. Harris R. Mobility as a service: benefits. 23rd World Congress on Intelligent Transport Systems; Melbourne 2016.
125. Hopkins PD, Dacey A. Vegetarian Meat: Could Technology Save Animals and Satisfy Meat Eaters? *Journal of Agricultural and Environmental Ethics*. 2008;21(6):579-96.
126. Jones T, Harms L, Heinen E. Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. *Journal of Transport Geography*. 2016;53(Supplement C):41-9.
127. Kent JL. Carsharing as active transport: What are the potential health benefits? *Journal of Transport & Health*. 2014;1(1):54-62.
128. Marikyan D, Papagiannidis S, Alamanos E. A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change*. 2019;138:139-54.
129. Mintel. Meat free foods. 2010.
130. Otero I, Nieuwenhuijsen MJ, Rojas-Rueda D. Health impacts of bike sharing systems in Europe. *Environment International*. 2018;115:387-94.
131. Russo A, Escobedo FJ, Cirella GT, Zerbe S. Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. *Agriculture, Ecosystems & Environment*. 2017;242:53-66.
132. Springmann M, Godfray HCJ, Rayner M, Scarborough P. Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences*. 2016;113(15):4146-51.
133. Stradling SG, editor *Proceedings of the Institution of Civil Engineers Municipal Engineer*; 2002.
134. Vainio A, Niva M, Jallinoja P, Latvala T. From beef to beans: Eating motives and the replacement of animal proteins with plant proteins among Finnish consumers. *Appetite*. 2016;106:92-100.
135. Fakhri El Khoury C, Karavetian M, Halfens RJG, Crutzen R, Khoja L, Schols JMGA. The Effects of Dietary Mobile Apps on Nutritional Outcomes in Adults with Chronic Diseases: A Systematic Review. *Journal of the Academy of Nutrition and Dietetics*. 2019.
136. Bhattacharya S. TaskRabbit: how an app can relieve you of all your chores: The Telegraph; 2015 [Available from: <https://www.telegraph.co.uk/technology/technology-companies/12026750/TaskRabbit-How-an-app-can-relieve-you-of-all-your-chores.html>].
137. Carplus. Annual survey of car clubs 2014/15. London; 2015.
138. Chan ND, Shaheen SA. Ridesharing in North America: Past, Present, and Future. *Transport Reviews*. 2012;32(1):93-112.
139. Gebhardt L, Krajewicz D, Oostendorp R, Goletz M, Greger K, Klötzke M, et al. Intermodal Urban Mobility: Users, Uses, and Use Cases. *Transportation Research Procedia*. 2016;14:1183-92.
140. Karlsson ICM, Sochor J, Strömberg H. Developing the 'Service' in Mobility as a Service: Experiences from a Field Trial of an Innovative Travel Brokerage. *Transportation Research Procedia*. 2016;14:3265-73.

141. Norfolk Car Club. General questions, 2017 [Available from: <https://www.norfolkcarclub.com/faqs/>].
142. Ong D, Moors T, Sivaraman V. Comparison of the energy, carbon and time costs of videoconferencing and in-person meetings. *Computer Communications*. 2014;50:86-94.
143. Stiglic M, Agatz N, Savelsbergh M, Gradisar M. Making dynamic ride-sharing work: The impact of driver and rider flexibility. *Transportation Research Part E: Logistics and Transportation Review*. 2016;91(Supplement C):190-207.
144. Weiss M, Dekker P, Moro A, Scholz H, Patel MK. On the electrification of road transportation – A review of the environmental, economic, and social performance of electric two-wheelers. *Transportation Research Part D: Transport and Environment*. 2015;41:348-66.
145. Lister K, Harnish T. The shifting nature of work in the UK - bottom line benefits of telework. *Telework Research Network*; 2011.
146. Filimonau V, Krivcova M, Pettit F. An exploratory study of managerial approaches to food waste mitigation in coffee shops. *International Journal of Hospitality Management*. 2019;76:48-57.
147. Food Tech Connect. Using big data to transform unfamiliar ingredients into tasty recipes 2016 [Available from: <https://foodtechconnect.com/2016/04/20/big-food-data-recipes-from-unfamiliar-ingredients/>].
148. O'Keefe P, Caulfield B, Brazil W, White P. The impacts of telecommuting in Dublin. *Research in Transportation Economics*. 2016;57(Supplement C):13-20.
149. Rodionova Z. Worlds first food waste supermarket so popular it has to open second branch after 9 months. *The Independent*. 2016.
150. Gerrie A. The growth industry: veg boxes have gone from a niche product for worthies to a foodies' essential: *Independent*; 2012 [Available from: <https://www.independent.co.uk/life-style/food-and-drink/features/the-growth-industry-veg-boxes-have-gone-from-a-niche-product-for-worthies-to-a-foodies-essential-6699778.html>].
151. Jones BA, Madden GJ, Wengreen HJ. The FIT Game: preliminary evaluation of a gamification approach to increasing fruit and vegetable consumption in school. *Preventive Medicine*. 2014;68:76-9.
152. Cairns S, Behrendt F, Raffo D, Beaumont C, Kiefer C. Electrically-assisted bikes: Potential impacts on travel behaviour. *Transportation Research Part A: Policy and Practice*. 2017;103(Supplement C):327-42.
153. Snow A. Americans ready for the smart home: *Coldwell Banker*; 2015 [Available from: <https://blog.coldwellbanker.com/americans-ready-for-the-smart-home/>].
154. Astegiano P, Fermi F, Martino A. Investigating the impact of e-bikes on modal share and greenhouse emissions: a system dynamic approach. *Transportation Research Procedia*. 2019;37:163-70.
155. Bekker GA, Fischer ARH, Tobi H, van Trijp HCM. Explicit and implicit attitude toward an emerging food technology: The case of cultured meat. *Appetite*. 2017;108:245-54.
156. Coroama VC, Hilty LM, Birtel M. Effects of Internet-based multiple-site conferences on greenhouse gas emissions. *Telematics and Informatics*. 2012;29(4):362-74.
157. Hern A. Uber claims new taxi-sharing service saves 120 tonnes of CO2 a month: *The Guardian* 2015 [Available from: <https://www.theguardian.com/technology/2015/apr/17/uber-taxi-sharing-service-saves-120-tonnes-co2-month>].
158. Hidrue MK, Parsons GR, Kempton W, Gardner MP. Willingness to pay for electric vehicles and their attributes. *Resource and Energy Economics*. 2011;33(3):686-705.
159. . !!! INVALID CITATION !!! .
160. Cornell L. Can car clubs work as part of the rural public transport mix? *Logistics & Transport Focus*. 2011;13(12):24-6.
161. Cretella A, Buenger MS. Food as creative city politics in the city of Rotterdam. *Cities*. 2016;51:1-10.

162. Denstadli JM, Gripsrud M, Hjorthol R, Julsrud TE. Videoconferencing and business air travel: Do new technologies produce new interaction patterns? *Transportation Research Part C: Emerging Technologies*. 2013;29(Supplement C):1-13.
163. Enoch MP, Taylor J. A worldwide review of support mechanisms for car clubs. *Transport Policy*. 2006;13(5):434-43.
164. Funk K, Rabl A. Electric versus conventional vehicles: social costs and benefits in France. *Transportation Research Part D: Transport and Environment*. 1999;4(6):397-411.
165. Garnett T. Growing food in cities - a report to highlight and promote the benefits of urban agriculture in the UK. National Food Alliance, SAFE Alliance; 1996.
166. Hynes M. Mobility matters - Technology, telework and the (Un)sustainable consumption of distance. 2013.
167. Kurz V. Nudging to reduce meat consumption: Immediate and persistent effects of an intervention at a university restaurant. *Journal of Environmental Economics and Management*. 2018;90:317-41.
168. Ozcan P, Mohnmann M, Krishnamoorthy C. Who shares and who doesn't? Results of the UK sharing economy consumer survey. Warwick Business School; 2017.
169. RUAF Foundation. Urban agriculture: what and why? 2017 [Available from: <https://www.ruaf.org/urban-agriculture-what-and-why>].
170. Department of Transport. Making car clubs work: a good practice guide. 2005.
171. Hsu C-L, Lin JC-C. An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives. *Computers in Human Behavior*. 2016;62:516-27.
172. Kamenetz A. Is peers the sharing economy's future or just a great silicon valley PR stunt? 2013 [Available from: <https://www.fastcompany.com/3022974/is-peers-the-sharing-economys-future-or-just-a-great-silicon-valley-pr-stunt>].
173. La Trobe H. Local Food, Future Directions. London; 2002.
174. Marsh S. The rise of vegan teenagers: 'More people are into it because of instagram' 2016 [Available from: <https://www.theguardian.com/lifeandstyle/2016/may/27/the-rise-of-vegan-teenagers-more-people-are-into-it-because-of-instagram>].
175. McDonald J. Consumers and Home Energy Management. POWERGRID International. 2014;19(4):14-7.
176. Nataliia L, Elena F. Internet of Things as a Symbolic Resource of Power. *Procedia - Social and Behavioral Sciences*. 2015;166:521-5.
177. Schubert C. Green nudges: Do they work? Are they ethical? *Ecological Economics*. 2017;132:329-42.
178. Simock N, Willis R, Capener P. Cultures of community energy. Lancaster University; 2016.
179. Travel Smart Surrey. Community and Taxis: Surrey County Council; 2017 [Available from: <https://pbnetwork.org.uk/travelsmart-funds-1m-of-community-transport-projects-in-surrey/>].
180. Heffner RR, Kurani KS, Turrentine TS. Symbolism in California's early market for hybrid electric vehicles. *Transportation Research Part D: Transport and Environment*. 2007;12(6):396-413.
181. Nour MM, Rouf AS, Allman-Farinelli M. Exploring young adult perspectives on the use of gamification and social media in a smartphone platform for improving vegetable intake. *Appetite*. 2018;120:547-56.
182. Axhausen KW. Social Networks, Mobility Biographies, and Travel: Survey Challenges. *Environment and Planning B: Planning and Design*. 2008;35(6):981-96.
183. Blythe PT, Holm C. Use of combi cards in automatic fare payment systems. *Traffic engineering & control : tec : the international journal of traffic management and transportation planning*. 2002;43(1):16-20.
184. Davison L, Enoch M, Ryley T, Quddus M, Wang C. A survey of Demand Responsive Transport in Great Britain. *Transport Policy*. 2014;31(Supplement C):47-54.
185. Hardy J. How could we buy energy in the smart future? : Imperial College London; 2017.

186. Mintel AI. New ridesharing service that matches drivers with people looking for a spare seat. Mintel; 2017.
187. Zhang Y, Mi Z. Environmental benefits of bike sharing: A big data-based analysis. *Applied Energy*. 2018;220:296-301.
188. Open Energi. CERT final report. OFGEM; 2012.
189. KPMG. Self driving cars: The next revolution. KPMG Group; 2012.
190. Mwasilu F, Justo JJ, Kim E-K, Do TD, Jung J-W. Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and Sustainable Energy Reviews*. 2014;34:501-16.
191. Byun J, Hong I, Lee B, Park S. Intelligent household LED lighting system considering energy efficiency and user satisfaction. *IEEE Transactions on Consumer Electronics*. 2013;59(1):70-6.
192. Morstyn T, Farrell N, Darby SJ, McCulloch MD. Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nature Energy*. 2018;3(2):94-101.
193. Ornes S. When your stuff spies on you 2017 [Available from: <https://www.sciencenewsforstudents.org/article/when-your-stuff-spies-you>].
194. Choo S, Mokhtarian PL, Salomon I. Does telecommuting reduce vehicle miles travelled? An aggregate time series analysis for the US. *Transportation*. 2005;32(37):37-64.
195. Algesheimer R, Dholakia UM, Herrmann A. The Social Influence of Brand Community: Evidence from European Car Clubs. *Journal of Marketing*. 2005;69(3):19-34.
196. Axsen J, Kurani KS. Interpersonal influence in the early plug-in hybrid market: Observing social interactions with an exploratory multi-method approach. *Transportation Research Part D: Transport and Environment*. 2011;16(2):150-9.
197. Fisher-Murray S. Sussex Uo, editor 2017. [cited 2019]. Available from: <http://blogs.sussex.ac.uk/sussexenergygroup/2017/02/14/transforming-the-low-energy-housing-sector/>.
198. Han L, Wang S, Zhao D, Li J. The intention to adopt electric vehicles: Driven by functional and non-functional values. *Transportation Research Part A: Policy and Practice*. 2017;103:185-97.
199. Levine M. Share my ride. 2009 26th April 2017.
200. Marshman H, Benjamin E. USA E-bike market waking up. *Bike Europe*. 2012.
201. Specht K, Sanyé-Mengual E. Risks in urban rooftop agriculture: Assessing stakeholders' perceptions to ensure efficient policymaking. *Environmental Science & Policy*. 2017;69:13-21.
202. White LV, Sintov ND. You are what you drive: Environmentalist and social innovator symbolism drives electric vehicle adoption intentions. *Transportation Research Part A: Policy and Practice*. 2017;99:94-113.
203. Schuitema G, Groot JIM. Green consumerism: The influence of product attributes and values on purchasing intentions. *Journal of Consumer Behaviour*. 2015;14(1):57-69.
204. Statista. Share of adults who own a smartphone in the UK: Statista; 2018 [Available from: <https://www.statista.com/statistics/956297/ownership-of-smartphones-uk/>].
205. Statista. Percentage of households with washing machines in the UK: Statista; 2018 [Available from: <https://www.statista.com/statistics/289017/washing-machine-ownership-in-the-uk/>].
206. Thomas S, Dudda C, Petersson P, Schuster K, editors. *Selling a Function Instead of a Product: Renting White Goods Via Functional Service Contracts (FUNSERVE)*. Energy Efficiency in Household Appliances and Lighting; 2001 2001//; Berlin, Heidelberg: Springer Berlin Heidelberg.
207. Böcker L, Meelen T. Sharing for people, planet or profit? Analysing motivations for intended sharing economy participation. *Environmental Innovation and Societal Transitions*. 2017;23:28-39.
208. Christensen C. *The Innovator's Dilemma*. New York: HarperBusiness; 1997.
209. Davis FD. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*. 1989;13(3):319-40.
210. Rogers EM. New product adoption and diffusion. *Journal of Consumer Research*. 1976;2(4):290-301.

211. Axsen J, Cairns J, Dusyk N, Goldberg S. What drives the Pioneers? Applying lifestyle theory to early electric vehicle buyers in Canada. *Energy Research & Social Science*. 2018;44:17-30.
212. Jensen M. Lifestyle: Suggesting mechanisms and a definition from a cognitive science perspective. *Environment, Development and Sustainability*. 2009;11(1):215-28.
213. Hur WM, Kim HK, Park JK. Food- and situation-specific lifestyle segmentation of kitchen appliance market. *British Food Journal*. 2010;112(3):294-305.
214. Jain R. Analysis of Indian Consumers' Behaviour using Lifestyle Segmentation. *Journal of Business Thought*. 2019;10(March):57-65.
215. Bassiouni DH, Hackley C. 'Generation Z' children's adaptation to digital consumer culture: A critical literature review. *Journal of Customer Behaviour*. 2014;13(2):113-33.
216. Too Good To Go. Save delicious food and fight food waste 2019 [Available from: <https://toogoodtogo.co.uk/en-gb>].
217. Warman M. Digital sector worth more than £400 million Department for Digital, Culture, Media & Sport; 2020 [Available from: <https://www.gov.uk/government/news/digital-sector-worth-more-than-400-million-a-day-to-uk-economy>].
218. Cullen R. Addressing the digital divide. *Online Information Review*. 2001;25(5):311-20.
219. Marcell K, Agyeman J, Rappaport A. Cooling the campus: Experiences from a pilot study to reduce electricity use at Tufts University, USA, using social marketing methods. *International Journal of Sustainability in Higher Education*. 2004;5(2):169-89.
220. Lee N, Kotler P. *Social Marketing: Influencing Behaviours for Good*: Sage Publications; 2012.
221. Cherry C, Scott K, Barrett J, Pidgeon N. Public acceptance of resource-efficiency strategies to mitigate climate change. *Nature Climate Change*. 2018;8(11):1007-12.
222. Yen Y-S, Wu F-S. Predicting the adoption of mobile financial services: The impacts of perceived mobility and personal habit. *Computers in Human Behavior*. 2016;65:31-42.
223. Department for Transport. National Travel Survey. Department for Transport Statistics; 2018.
224. Kantar World Panel. Grocery Market Share. 2018.