Mixed feelings: a review and research agenda for emotions in sustainability transitions

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Mixed feelings: A review and research agenda for emotions in sustainability transitions

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Abstract

Low-carbon transitions across energy and transport systems have been widely researched in regards to how transitions are designed, what policies support them, which technologies they entail, and how fast, or slow, they take. Much of this research has focused on examining the agency and behaviour of actors and institutions, or examining processes and outcomes, but less weight has been given to human emotions. Based on an explorative systematic review of the sustainability transitions literature, we address a research gap by focusing on how emotions have been reported or examined in transitions concerning energy, buildings and transport. We show that the acceptability and adaptation of new technologies, systems, policies and practices requires people's willingness to change, which itself needs positive emotional commitment. We thus propose a new research agenda for low-carbon transitions that takes into consideration people's emotions as we address climate change and attempt to move to net zero societies.

Keywords

Emotions; feelings; sustainability transitions; energy; transport; buildings

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1 Introduction

Sustainability transitions have amassed a large body of scholarly research as climate change and resource scarcity continue to require radical change in sociotechnical systems, in particular in the areas of energy, transport and buildings (Markard et al. 2012; Smith et al. 2010; Köhler et al. 2019). This previous body of work has had a wide conceptual and interdisciplinary reach spanning in particular innovation studies, political science, social science and economics (see Section 2). Over ten years ago, Shove and Walker (2010:471) argued that research on "*sociotechnical transitions and their governance tends to concentrate on the introduction of new technologies and systems of supply*" and that more attention was needed to the 'socio' part of sociotechnical transitions. Köhler et al. (2019) agreed concluding that less attention has been given in this scholarship to the more 'complex and messy' human dimensions (see also Zolfagharian et al. 2019). In this paper, we therefore address a research gap and show, via a systematic and exploratory review of previous research, that *emotions* and emotional responses to the development and use of systems such as energy, transport and buildings (we focus on these three sectors given that they produce the main bulk of global greenhouse gas emissions) are a particularly under-researched area within sustainability transitions (see also Feola and Jaworska 2019).

Emotions are a key part of human existence, and they influence the way we think, understand the world around us and make decisions (Izard 2009; Volz and Hertwig 2016). Perlaviciute et al. (2018), for example, have shown that many low-carbon energy projects have been halted due to negative public emotions that were overlooked, and even ignored, by practitioners, industry and policy makers who did not know how to address them (see also Rohse et al. 2020). Some research in energy development has examined emotions, most in relation to emotions about place in regards to extractive developments, with research shown that "*energy and resource sectors have a damaging tendency to sideline and dismiss emotions*" (Rohse et al. 2020: 137). We show via our explorative and qualitative, yet systematic review that emotions, however, matter and that there is a need to take them into account as, for example decisions about developments like low-carbon energy systems, are not purely cognitive processes, but also include emotional responses across different stakeholders (Brosch et al. (2014; also Kals and Muller, 2012). This is particularly important in sustainability transitions which involve decision making over new, and often disruptive,

innovations (Kivimaa and Kern 2014), that can provoke strong emotions such as desire, fear or anger (e.g. Alborg 2018, Huijts 2018). Understanding people's emotional responses to low-carbon transitions is therefore vital, given that the acceptability of new innovations requires positive emotional commitment. If emotions are not accounted for, it may artificially narrow the scope of research given that many people are likely to have strong emotional response to topics such as climate change, energy provision and transport, as such topics can be complex and may thus exceed people's factual knowledge, meaning more reliance on emotional responses to process decisions about them (e.g. Schmidt et al. 2017; Pánek and Bendiktsson 2017; Brown et al. (2019).

Here we make an attempt to examine whether, and how, emotions have *explicitly* been researched in previous sustainability transitions literature. In this paper, we therefore ask: *How have emotions been examined in sustainability transitions research*? We answer this question via a systematic review of peer-reviewed academic literature focusing explicitly on how emotions, whether positive and negative (or neutral), have been reported or examined in previous transitions research in the areas of buildings, energy and transport. We highlight a research gap and make a contribution towards developing a research agenda for the transitions research field by showing that only a limited amount of research has examined human emotions and that this is an area that warrants further academic enquiry.

Our paper is arranged as follows: Section 2 shows an existing research gap in relation to emotions in sustainability transitions. In Section 3 we outline what emotions are and introduce a typology of emotions from previous literature and how they may be relevant in sustainability transitions. Section 4 explains our systematic review method. Our results are presented in Section 5, divided into three parts: type of emotions, the technology or sociotechnical system they are connected with, and their temporality. Section 6 proposes a research agenda, while Section 7 concludes.

2 The human dimensions of sustainability transitions

Sustainability transitions entail a shift from one sociotechnical system, usually a polluting one, to a to a more sustainable one, involving a shift in technologies, institutions, regulation, practices, routines and meanings etc. (e.g. Schot and Geels 2008). Examples of these include for example a shift from fossil fuels to renewable energy in electricity provision or the use of electricity instead of petrol to power cars. Sustainability transitions

have been roughly divided into three phases (Schot and Kanger 2018; Kanger et al. 2019). Emergence describes the birth of new sociotechnical systems and associated rules in several niches in parallel without much coordination. Acceleration is when niches grow rapidly, and scale up, overcoming hurdles of commercialization. Stabilization happens when new innovations begin to saturate markets, and achieve widespread dissemination and use. Similarly, Geels et al. (2017) discuss a conceptual framework for low-carbon transitions where an initial phase depicts radical innovations emerging on the fringe before they enter small markets that promote development and specialization; an intermediate phase depicts breaking through more widely and begin to compete with established infrastructures; and a final phase of becoming dominant and substituting for the incumbent technologies.

As mentioned in Section 1 Introduction, a large body of scholarship has examined sustainability transitions from different angles and across many dimensions (e.g. Köhler et al. 2019, Zolfagharian et al. 2019).

Historically, previous research has in particular focused on which technologies (e.g. Abas et al. 2015; Kittner et al. 2017) and institutions transitions entail (e.g. Moss et al. 2015); and the processes by which they are designed and governed (e.g. Sovacool and Martiskainen, 2020) and whether entities such as 'the state' or concepts like 'power', or who has power, matter (Johnstone and Newell 2018). Work on policies, or mixes of policies, has paid particular attention on which measures and initiatives have supported or hindered them (e.g. Edmondson et al. 2019; Reichardt and Rogge 2016; Rogge et al. 2020). Research has also been interested in how transitions develop in different phases from start-up to acceleration and diffusion (e.g. Schot and Kanger 2018), and how fast, or slow, they have been (e.g. Sovacool 2016) and across which spatial scales (e.g. Bridge et al. 2013).

When it comes to examining people and their role within sustainability transitions, concepts such as user innovation (e.g. Schot et al. 2016, Halbinger 2018), intermediation (e.g. Kivimaa et al. 2019) and leadership (e.g. Martiskainen 2017) are well-established. Research has examined how people have developed, tinkered, adapted, adopted and promoted innovations (e.g. Meelen et al. 2019). Different types of users (Schot et al. 2016, Martiskainen et al. 2021) have been identified, from those developing disruptive, radical, innovations in niches (e.g. Hossain 2018), to those facilitating and maintaining incumbent regimes (Sovacool et al. 2020b). The agency and power of different actors with/in transitions has also had its own share of research (e.g. Stirling 2014). Work on

intermediaries in particular has shown them to range from neutral facilitators to powerful allies (e.g. Kivimaa et al. 2019; Mignon and Kanda, 2018; Martiskainen and Kivimaa 2018).

On the role of people within low-carbon transitions, concepts and actions such as motivations (e.g. Busch and McCormick 2014; Hicks and Ison 2018; Joas et al. 2016); experimenting (e.g. Coenen et al. 2010, Rosenbloom et al. 2018, Torrens et al. 2018); how people learn or share learning (e.g. van Mierlo et al. 2020; Domènech et al. 2015; Van Poeck et al. 2020; Schot and Geels 2008), and social acceptance (e.g. Delicado et al. 2016; Komendantova and Battaglini 2016; Yazdanpanah et al. 2015) have been widely researched in relation to what encourages people to uptake for example new technology or practices and sustain them for the longer term.

Research has also been called to examine not only the success of transitions but whether they have aspects that are less successful (e.g. Antal et al. 2020) and the field has examined aspects such as fairness and justice, i.e. whether transitions are benefiting everyone equally (e.g. Della Bosca and Gillespie 2018; Healy and Barry 2017; McCauley et al. 2019), and how transitions could improve human wellbeing (e.g. Köhler et al. 2019). Culture has been examined too (Sovacool and Griffiths 2020), as well as the role that art and design could have in influencing and enabling sustainability transitions (e.g. Pelzer and Versteeg 2019).

However, despite the breadth of research within this field, and an increasing focus on the more human dimensions of sustainability transitions such as justice and wellbeing—as we later show via the systematic review—there has been a relatively limited study focusing specifically on emotions, and people's emotional responses to specific innovations or technologies, policy processes, or wider sustainability transitions.

3 Conceptualizing and typologizing emotions in relation to sustainability transitions

Emotions have been widely conceptualised in psychological and behavioural research, but less investigated in other domains of social science and humanities inquiry. Despite this lacuna, emotions are a critically important part of how people, especially consumers or potential adopters, choose lifestyles or new technologies. There is a strong link and complementarity between emotions and cognition (Brosch et al. 2014). Emotions are not peripheral to reason and decision-making, but they are instead "*as essential as*

logical reasoning" and "*as likely to enhance rationality as to subvert it*" (Mair et al. 2019: 48). Emotions can have different intensities and can be experienced as motivational and informational (Izard 2009), which in turn influence our thoughts, tendency to act, and actions (Izard 2009). There are also conscious events and causal events in relation to emotions (Feldman Barrett et al. 2007). For example, an angry person will be less likely to seek independent information or knowledge, and more likely to adopt a closed mind; conversely, an anxious person could provoke a deeper processing of information and a change in viewpoints (Mair et al. 2019). Emotions can thus reveal the "hidden rationalities" behind why people behave the way they do, and they can also act as critical "contextual cues" that modulate perception, focus attention, and determine what is remembered (or forgotten) (Clore 2011; Forgas 2014; Nesse et al. 2009; Pessoa 2013; Feldmarn Barrett 2017; Okon-Singer et al. 2018; Meshulam et al. 2012). As anyone who has ever laughed in a crowd already knows, emotions can also spread, they can be contagious, meaning positive or negative emotions can cascade outward from a single individual to "infect" or affect others (Cuppen et al. 2020).

When discussing emotions, we often think of strong feelings such as love, fear or anger. However, it is not easy to define exactly what an emotion is, as the concept has largely been left without a single definition (Izard 2009). Izard (2009) for example distinguishes emotions from 'emotion feelings', defining emotion feelings as a phase of neurobiological activity that form key motivational aspects of emotions, which in turn motivate human behaviour (Izard 2009). Put more simply, Feldman Barrett et al. (2007: 391) write that "*At its core, the experience of emotion can be described a contentful state of pleasure or displeasure*." Initially emotions were linked to facial expressions, but these were later extended to also include emotions that are not encoded in facial expressions (Ekman 1999, Izard 2009). The four basic emotions of fear, grief, love and rage identified as far back as the late 1880s (Izard 2009) have, over the years, been expanded by numerous scholars (Lazarus and Lazarus 1994). For example, Cowen and Keltner (2017) showed 2,185 emotionally evocative short videos to 853 participants and found 27 distinct varieties of self-reported emotional experience. They then identified a total of 34 emotion categories.

Given our focus on examining emotions in low-carbon transitions, the aim of our paper is not a conceptual development of emotions. Instead, we follow conceptualisations established in previous social psychological research. Here, we build on Robinson (2008)

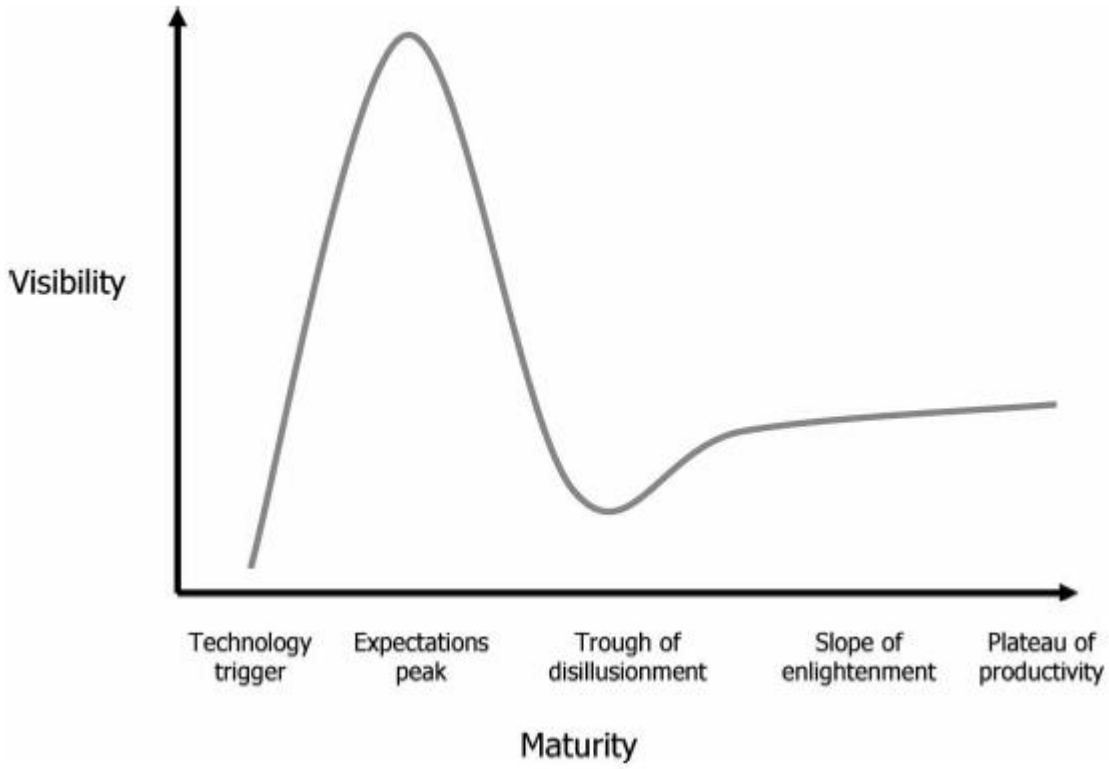
198 who developed a typology of emotions in terms of the types of emotions (related to object
199 properties, future appraisal, events, self-appraisal, social contexts, cathected emotion) and
200 whether they are positive or negative (see Table 1).
201
202 **Table 1: A typology of emotions for low-carbon sustainability transitions**

Kind of emotion	Positive emotions	Negative emotions
Emotions related to object properties (e.g., a new energy technology or innovation)	Interest, curiosity	Alarm, panic
	Attraction, desire, admiration	Aversion, disgust, revulsion
	Surprise, amusement	Indifference, familiarity, habituation
Future appraisal emotions (e.g., a new policy, scenario, vision or projection)	Hope	Fear
Event related emotions (e.g., a climate-related natural disaster, an oil embargo, a strike)	Gratitude, thankfulness	Anger, rage
	Joy, elation, triumph, jubilation	Sorrow, grief
	Relief	Frustration, disappointment
Self-appraisal emotions (e.g., learning about energy efficiency, changing lifestyles to be less carbon intensive)	Pride in self achievement, self-confidence, sociability	Embarrassment, shame, guilt, remorse
Social emotions (e.g., engaging in social networks, intermediating on behalf of others)	Generosity	Avarice, greed, miserliness, envy, jealousy
	Sympathy	Cruelty
Cathected emotions (e.g., connected to or invested with a particular government figure, a spokesperson, a family member)	Love	Hate

203 Source: Modified from Robinson (2008).
204
205 In terms of emotions and their relevance to sustainability transitions, literature from
206 other fields can guide us in this regard. For example, the field of sustainable consumption
207 has examined how people make purchasing decisions and what their emotional response is
208 to certain options (e.g. Rezvani et al. 2018). Despite sustainability policies usually aiming for
209 wider change and better environmental, economic and social outcomes for all, they have
210 often been framed through rather individualistic and largely voluntary sustainable
211 consumption decisions and practices (e.g. Lim 2017; Middlemiss 2014). Here issues like the
212 impact of marketing strategies on purchasing, or non-purchasing decisions, rely heavily on
213 people's emotional responses (Lim 2017). The literature on the "sociology of expectations"
214 or "anticipation" can provide further insight on this as it mentions the feelings of hope,

exuberance, and excitement that can accompany new innovations (such as electric vehicles or hydrogen fuel cells) before they rapidly fade away as hype dissipates and more realistic assumptions set in (Bakker et al. 2011; Van Lente 2000; Van Lente 2012). This literature even proposes that once a technology's expectations "peak", realizations often fall through a "trough of disillusionment" where excitement wanes, a process shown in Figure 1.

Figure 1: The temporality of expectations associated with new technologies



Source: Modified from Table 3 from Sovacool and Hess (2017), based on various studies in the sociology of expectations literature. See references there for more detail.

Conversely, other work on the history of technology suggests that feelings of fondness or nostalgia may come to associate with older, established technologies, notably things like hydropower dams, or coal fires and wood stoves, or candles or other old-fashioned lights, or classic cars. Hydropower dams and nuclear reactors have even been considered "technological sublime" throughout recent history in the United States (Nye 1994). Steam power, steamships, locomotives, and miniature steam generators were seen as "sublime" in their ability to solve social ills, lighten the toil of workers and housewives, provide faster and cleaner forms of transport, and revolutionize food production on the

farms. There could be a general trend with expectations about energy, and transport, systems that start with utopian exaggerations, and then move to normalization and eventual disillusionment, and then, after technologies are abandoned or evolve, nostalgia (Sovacool 2019). Emotions could thus be particularly relevant in regards to expectations, and subsequent acceptability, of specific low-carbon transitions (e.g. Hielscher and Sovacool 2018).

4 Research Methods

To gain an in-depth insight in the state of the art of emotions and low-carbon transitions, we conducted a systematic review of previously published, peer-reviewed, academic literature. This is a widely used method across the social sciences (Petticrew & Roberts 2006), and has been identified as a suitable tool in energy research (Sorrell 2007; Sovacool et al. 2018), given that it avoids bias and enables the inclusion of otherwise overlooked material (Hook et al. 2020). It is a useful tool enabling an overview of literature on a specific subject matter.

4.1 Search terms, timeline and database

Our data collection had the following main four steps:

First, we identified a suitable timeline for our search. We decided to include articles published between 2000-2020 on sustainability transitions, which has become an established research field of its own in this time period. As Markard et al. (2012: 957) write: "*Socio-technical transitions, system innovations, and the emergence of sustainable technologies have received increasing attention in the social-sciences over the past 10–15 years, and a number of conceptual frameworks have been developed for the study of these processes*". We thus felt that starting from the year 2000 would enable us to map the state of the art in sustainability transitions studies and capture the timeline of research into low-carbon transitions specifically. However, we recognise that earlier research in the fields of sustainable development, environmental protection, and energy consumption behaviours for example are relevant for our study (and could be explored in future research (see also Section 6).

Second, we chose 14 main terms as keywords to use in our search (see Table 2). These reflected the inclusion of emotions, low-carbon transitions, and different sectors of

energy, transport and buildings—we chose these sectors given their respective high emissions and hence importance to low-carbon transitions. We appreciate that there are other sectors also relevant for sustainability transitions, and we elaborate on this point further in Section 4.3. The combination of these keywords resulted in a total of 128 searches.

Third, we undertook keyword searches in academic database Scopus. We chose Scopus as it is the largest academic database in the world and has the widest coverage and scope, including 75 million records from more than 23,500 peer-reviewed journals and 5,000 publishers (Scopus 2020). Scopus is also available to most universities, goes back to 1970 and is therefore both historically relevant and accessible. This was considered key in case anyone wishes to repeat our study. We chose published papers to ensure focus on research that has gone through a rigorous peer review process, and articles published in English only, so as to make the study more replicable. Our searchers used four different boolean search combinations of the 14 main keywords (see Table 2), resulting in a total of 128 searches. We used keywords to match searches in "Article title, abstract and keywords" in all fields. Our initial search resulted in a total of 9,253 potentially relevant manuscripts.

Table 2: Keywords and search combinations

Keyword 1	**[AND] Keyword 2**	**[AND] Keyword 3**	**[AND] Keyword 4**
Emotion* [OR] Feeling* [OR] Sentiment* [OR] Sensation*	Low-carbon [OR] Low carbon [OR] Zero carbon [OR] Sustainab*	Energy [OR] Transport* [OR] Mobilit* [OR] Building* [OR] Housing	Transition*

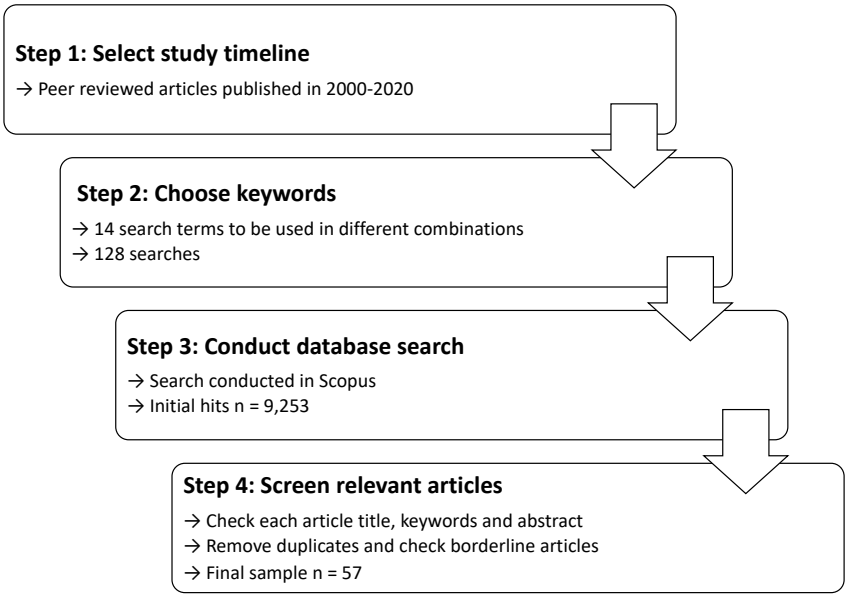
Source: Authors

Fourth, we screened all 9,253 initial articles based on the following inclusion criteria: We checked each study for its relevance to our aims and objectives and excluded any articles that were not related to emotions, or to the three sectors, or to the field of sustainability transitions. For example, our initial searches found many articles in the medical sciences field such as neuroscience, nursing, or clinical medicine, which were excluded. Or, studies may have utilized the word "feeling" or "sensation" but not to describe an emotion. Or, studies were not about energy as a fuel or service but for dietary needs ("nutritional energy") or biology ("cellular energy") or health ("joint mobility") and so

on. This initial screening left 694 remaining articles and after reading each article title, keywords, and abstract closely, and removing duplicates, we were left with 57 articles.

For this final sample of 57 articles, we read each article in full and from this closer reading, it became apparent that some articles only mentioned the word emotion once or twice, without focusing on the topic in depth. We therefore decided that to be included in our final coding sample an article had to have the word 'emotion*' at least three times in the main article text, and have more than a passing mention of emotions, so in other words, at least a partial focus on this topic. This left 28 articles that were then fully coded in our data analysis (see also Figure 2).

Figure 2: Systematic review process on emotions and sustainability transitions



Source: Authors

4.2 Data analysis

We used content analysis to examine each article in-depth, and used NVivo software for categorising our coding. The content analysis included first more descriptive data of each article such as publisher, main research question, theoretical approach, types of methods used, location of research, low-carbon problem addressed and low-carbon solution proposed. Then, coding was conducted according to the type of emotions mentioned in the

article. This was based on the range of emotions outlined in the typology by Robinson (2008) (and shown in Table 1 earlier). Our main nodes were emotions related to object properties, future appraisal, events, self-appraisal, social contexts, and cathected emotion, and then each main node had sub-nodes for both positive and negative emotions. Each time any of these emotions was mentioned in an article, it was coded. This included coding all instances to get an overview and include all mentions of emotions (i.e. whether as part of an article's literature review, theoretical approach, methods, results, discussion and/or conclusions). As different positive and negative emotions could have been mentioned within the same sentence, we did not calculate how many times each emotion was mentioned to avoid double counting. We also coded emotions that did not clearly fit within the typology under 'other emotions'.

Once coding was completed, each coded text and node was double checked for accuracy by the research team. Based on our coding, we then analysed our results thematically in the following three main steps. First, we categorised the different emotions in our data set based on the main categories in the Robinson (2008) typology already mentioned above (see Section 5.1). Second, based on this previous categorisation, we aimed to see if a specific technology or transition (e.g. in energy, buildings and transport) was linked to any specific set of emotions (see Section 5.2). Third, we categorised these technologies according to their maturity and commercial readiness, to see if there was any indication of a temporal element and how emotions may change during a technological change or wider transition (see Section 5.3).

4.3 Study limitations

Our study notably has some limitations. First of all, we conducted our systematic literature review in the English language, and therefore any academic peer reviewed articles in other languages were not included in the search. We also used only one database, Scopus, albeit it being one of the largest academic databases in the world, with 75 million records from more than 23,500 peer-reviewed journals and 5,000 publishers (Scopus 2020).

Moreover, our review is explorative and meant as a starting point. It builds on the handful of papers which have taken a specific focus on emotions in the field of energy, buildings or transport related transitions (e.g. Brosch et al. 2018; Kershaw et al. 2018; Rohse et al. 2020; Wright 2018), yet our keywords were also limited to these three sectors (albeit

high emission producing ones). Our search and analysis were guided by the typology of Robinson (2008) and due to resource limitations, we did not use all of the 47 different emotions in Robinson's typology as search terms, but instead used an 'umbrella' approach, and selected four main words, i.e. 'emotion*', 'feeling*', 'sentiment*', and 'sensation*' as main search terms, with a view that these could capture other emotion words. This however means that papers using other words (and not mentioning 'emotion*', 'feeling*', 'sentiment*', and 'sensation*'), could have been left outside of our sample. The specific focus on three sectors and the way we used search terms means that our sample is small, and there can thus be interesting and relevant papers outside these sectors and search terms that could have been overlooked and deserve further examination.

In addition, our coding protocol was based on the typology of emotions by Robinson (2008), which we chose as it gives a broad overview of a range of different types of emotions. However, it is not exclusive and therefore there are likely to be other emotions outside this typology (see for example Cowen and Keltner 2017). We also did not examine the depth of these emotions or their inter-connections.

Nevertheless, we hope that this review acts as a catalyst for further studies in other areas and sectors relevant to sustainability transitions. This could include research in sectors that contribute to greenhouse gas emissions and have inherent emotional connections. For example, these could include food and diets, and the transition from meat eating to plant-based diets which has relevance for the agricultural, farming, fishing, land use and water sectors. Another key trend, sustainable consumption, ultimately has connections to product life-cycles and waste in particular. We elaborate on areas for further research in Section 6.

5 Results and Discussion: Emotions in sustainability transitions

We next present our results in three main parts: an inventory of emotions, the technology or sociotechnical system they are connected with, and their temporality.

5.1 An inventory of emotions

In our review, we found a vast array of emotions connected to sustainability transitions, far more than we believe have been identified in a single paper before. This creates a useful

380 inventory shown in Table 3, which also offers examples of frequency (how many times they
381 came up in the literature) and empirical examples.

382

383 **Table 3: An inventory of emotions from our systematic review**

Emotions related to	Positive emotions *(frequency)*	Empirical example	Negative Emotions *(frequency)*	Empirical example
Object properties	Interest Desire Surprise *(11 articles)*	"An electrified home is among the things associated with modernity that many Tanzanians desire" (Ahlborg 2018: 269)	Alarm Panic Disgust Neglect Suspicion *(6 articles)*	"Those in the alarmed group (18% of Americans) are much more likely to report being convinced of the reality and danger of climate change and to feel sad, disgusted, angry, or afraid." (Doherty and Clayton 2011: 269)
Future appraisal	Hope *(10 articles)*	"This [*coal*] fire had a larger symbolic significance for the mother, installed in the hope that it would encourage her teenage son, a heavy drinker, to stay in during the evenings" (Wright 2018: 446)	Fear *(14 articles)*	"Exposure to [*electric vehicles*] EVs can additionally assuage fears of range anxiety, a factor regarded a major hurdle to EV adoption." (Kershaw et al. 2018: 684)
Events	Gratitude Joy Relief *(12 articles)*	"Our respondents declared that being able to see the impact they made by taking care of their surroundings created a feeling of gratification and contentment that small things made a big difference." (Mälgand et al. 2014: 44)	Anger Rage Grief, Frustration Disappointment *(14 articles)*	"One woman recalled her disappointment at her microwave, frustrated with how it took up too much room in her kitchen" (Wright 2018: 445)
Self appraisal	Pride *(10 articles)*	"Pride, work ethic, salt of the earth, "getting hands dirty" is not a figure of speech, but a reality in a mining town." (Della Bosca and Gillespie 2018: 734)	Embarrassment Shame Guilt *(7 articles)*	"While not stated explicitly by the participants in their climate stories, almost all participants expressed feelings of guilt and shame during the discussions on climate change." (Henderson and Wamsler 2020: 352)
Social	Generosity Sympathy *(10 articles)*	"Empathy is, we argue, a critical but hitherto neglected variable in sustainability research because of	Greed *(3 articles)*	"Local citizens are being selfish and parochial, unwilling to face any personal costs from energy projects" (Perlaviciute et al. 2018: 3)

		its central role in human-environment relations. (Brown et al. 2019: 16)		
Cathected	Love *(2 articles)*	"Feelings, ranging from sentimental attachment to love and fear, drove energy choices and shaped energy flows within the home." (Wright 2018: 443)	Hate *(1 article)*	"A perceiver who is driven by hatred organizes his perception differently from one who is driven by love." (Frank 2014: 677)
Other	Sense of security Sense of wellbeing Feeling connectedness Feeling of belonging Feeling of privacy Cosiness Solidarity Trust Serenity Calmness Coolness	"The miners themselves did not talk about intimacy at length, and more often obliquely through practical examples of co-operation and assertions of strong loyalty. Nevertheless the 'camaraderie' fostered underground was a recurring theme, also figuring in other participants' accounts and often in our wider conversations in the village. It was clearly fundamental to community life. Indeed, it was explained, the strength of the community bonds could not be understood without understanding the solidarity and mutual dependence deeply rooted in this affectual crucible of the small underground spaces, where lives depended on co-operation." Rohse et al. 2020:141).	Blame Fatigue Sense of isolation Pain Resistance	"Because of the shortage of active members, the emotional well-being of those members who are actively involved suffers: excessive demands, stress and a sense of frustration have a highly negative influence on people's ability to fulfil their need for subsistence and protection, while active members additionally show signs of fatigue." (Centgraf 2018:116).

384 Source: Authors. See also Data in Brief file for more details on empirical evidence.
385
386

5.1.1 **Object properties emotions (desire / alarm)**

Positive emotions linked to object properties (11 articles) included *desire* for electrical appliances such as fridges when they first emerged in UK households in the 1950-60s (Rohse et al. 2020) or people dreaming of gas-fired appliances (Wright 2018). In later times, millions still lack access to energy services, and for example in Tanzania, access to electricity is desired as a way for a better life (Ahlborg 2018). Desire also featured in Nunez-Cacho et al. (2018) study on a family firm moving to a circular economy business model so as to preserve the company for future generations, while (Wells and Nieuwenhuis, 2018) examined consumers' desire for product longevity in the automobile industry. Negative feelings of *alarm* featured in 6 articles. Doherty and Clayton (2011) report a range of emotions in the US about climate change, including people feeling disgusted. Perlaviciute et al. (2018) found that developments such as wind energy and biomass plants could evoke negative emotions of resistance if their development was forced on local communities from top down. Often smaller scale community energy projects are developed to avoid such ill-feelings, though even in such projects Centgraf et al. (2018) found that the families of those very active in a German energy cooperative sometimes felt neglected due to the dedication given to the cooperative. At a more domestic scale, for those who have desired new electrical home appliances for example, the arrival and use of such items can cause suspicion and confusion (Rohse et al. 2020).

5.1.2 **Future appraisal emotions (hope / fear)**

The positive future appraisal feeling of *hope* was mentioned in 10 articles. Hope was central with people engaging with the 'story' of climate change (Hendersson and Wamsler 2020) and protecting the environment (Rogers et al. 2012). Hope was also prominent in every day energy practices. Tanzanian villagers were hoping to ease poverty through energy access (Ahlborg 2018); members of a German energy co-operative dreamed of creating a considerate community (Centgraf 2018); and Danish Transition Town residents hoped to inspire others to embark on sustainable living (Mälgand et al. 2014). The negative future appraisal feeling of *fear* featured in the most number of articles (14 articles). Doherty and Clayton (2011) summarised a range of emotional concepts related to fear, all of which can negatively impact wellbeing, including "solastalgia", "environmental anxiety" and "eco-anxiety". Fear of the future was mentioned on one hand in relation to climate change, but

also on the other hand on the impacts that low-carbon energy transitions such as a move away from coal means to local communities (Della Bosca and Gillespie 2018). Fear also featured in much reported EV "range anxiety" (Kershaw et al. 2018), but also in relation to large energy developments such as nuclear, hydrogen, hydropower, wind (Perlaviciute et al. 2018) and high voltage power lines (Lienert et al. 2015).

5.1.3 Event related emotions (joy / anger, grief)

Joy and gratitude featured in 12 articles. People felt joy in driving EVs (Kershaw et al. 2018) and bikes (Yin et al. 2019), or living in eco-communities (Mälgand et al. 2014) or near greener energy projects (Perlaviciute et al. 2018). At home, people enjoy the warmth of electric blankets, the noise of gas boilers; and lit coal fires bringing family members together (Wright 2018). The joys of having a warm coal fire were also closely linked to negative event related feelings of *grief*, *loss* and *sadness* (14 articles), in particular with the move away from coal in Australian mining communities, many of which had a long mining history spanning decades (Della Bosca and Gillespie 2018). The sense of loss can be multi-fold, relating to the loss of: a job and livelihood; mining community; identity; and home and place if people are forced to leave to look for work elsewhere (also Doherty and Clayton, 2011; Rohse et al. 2020). This sense of loss is also felt in more tacit every-day encounters, including the loss in the sensory experience of living in a coal-fired home (Rohse et al. 2020) and the loss of home décor such as the coal fire mantelpiece used to show "sentimental" objects (Wright 2018). Nevertheless, the driver for this move away from coal, i.e. climate change, also raised a lot of negative emotions, especially anger (Doherty and Clayton 2011; Hendersson and Wamsler 2020).

5.1.4 Self-appraisal emotions

The positive self-appraisal feeling *pride* (10 articles) was mentioned by drivers who felt better about themselves by driving an EV (Kershaw et al. 2018, also Brosch et al. 2018) or those who took part in sustainable energy projects (Ahlborg 2018; Centgraf 2018). Pride was also felt in association to being a member of a certain community or industry, like an eco-villager (Mälgand et al. 2014) or a coal miner (Della Bosca and Gillespie 2018). While consuming green products like EVs can bring pride, consumption can also lead to negative emotions of *shame* and *guilt* (7 articles). At domestic household scale, people feel guilty

about using or wasting energy (Brosch et al. 2018; Wright 2018), or making climate change worse by unsustainable behaviours such as flying (Henderson and Wamsler 2020). Such consumerist values often cause other negative impact such as unhappiness, depression and anxiety (Rogers et al. 2012).

5.1.5 Social emotions

The positive social feelings of *generosity* and *empathy* were prominent in 10 articles. Brown et al. (2019) for example argue that sustainability research ought to pay more attention to empathy, given its central role in creating cultural meaning and embedding pro-environmental behaviour (see also Sleenhoff and Ossewijer 2016; Mälgand et al. 2014). Thoughts for future generations encountered in how people felt about solidarity for others in the face of climate change (Brown et al. 2019), but also in cases were communities such as coal mining towns were facing demise (Della Bosca and Gillespie 2018). Negative social emotion *greed* featured in 3 articles, with people for example bragging about wasteful use of energy at home (Wright 2018). Wasteful behaviours were also linked to people's feelings about large scale technologies such as carbon capture and storage (CCS) which would ultimately allow people to continue their fossil fuel use (Perlaviciute et al. 2018), and further increase the gap between 'haves' and have-nots' which Doherty and Clayton (2011) indicated as one consequence of also climate change.

5.1.6 Cathected emotions (love / hate)

One of the less often mentioned or discussed emotions were cathected emotions (that is, those that become attached to a particular entity, a person, object, or idea) of *love* and *hate*. Love was explicitly mentioned in two articles (Wright 2018, Frank 2014), whereas hate in only one (Frank 2014). When love was discussed, it nevertheless was shown to have a strong resonance to energy practices and appliances. Wright (2018) for example described a woman who loved her 30 year-old electric cooker despite it needing regular repairs and being the joke of the family.

5.1.7 Other emotions

Lastly, our review unveiled a host of other emotions that did not neatly fit the categories in the Robinson typology. These included both positive and negative emotions.

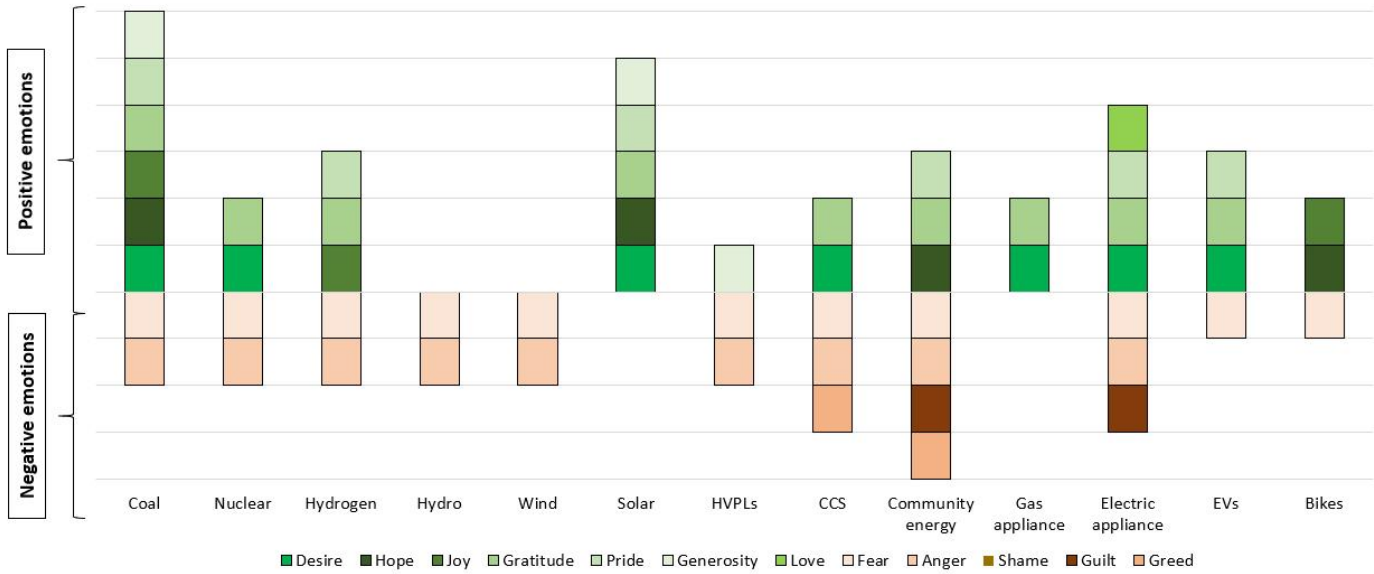
For example, studies mentioned a positive *sense of wellbeing* related to technologies such as smart lighting which can provide comfortable indoor spaces (Lumpkin et al. 2020; Wang et al. 2018), but also *positive emotional attachment* to technologies or practices such as sitting around coal fires or heaths (Wright, 2018). Different forms of energy production enabled people to *feel connected* to places and communities, examples of which included an attachment to coal mining towns (Rohse et al. 2020) as well as positive emotions associated with running community renewable energy projects (Feola and Jaworska 2019; Malgand et al. 2014). However, these could also have negative emotions, such as people feeling *resistance* towards new energy projects in their locality that then affected their wellbeing, or— in the case of community renewable energy projects— feeling *fatigue* due to excessive commitments required for successful projects (Centgraf, 2018). This category of "other emotions" reveals that in many cases, emotions may also be mixed and context dependent by location, type of technology, or type of community or individual.

5.2 Emotions connected to specific low-carbon sustainability transitions

The emotions associated with low-carbon transitions can be categorized not only by their type, but also the technology or sociotechnical system they are connected with. This essentially reveals which emotions are associated with which technologies as well as their corresponding energy services or functions.

Indeed, as Figure 3 reveals, 13 different technologies were mentioned explicitly alongside some emotion, including some sources of energy supply (nuclear, hydro, coal), some end use devices (appliances, vehicles), and sources of delivery such as high voltage power lines. Across these technologies, seven positive emotions recur: desire, hope, joy, gratitude, pride, generosity, and love. Five negative emotions recur: fear, anger, shame, guilt, and greed. Interestingly, within our sample, some technologies have only positive emotions reported from the literature, e.g. gas appliances and solar energy. Some, surprisingly, have only negative, e.g. hydropower and wind power. Many more have mixed emotions, some as many as a bundle of seven combined positive and negative emotions (see Figure 3). In terms of decarbonization, our analysis shows that both low-carbon innovations and fossil fuels have positive emotions; but both also have a suite of negative emotions.

Figure 3: The positive and negative emotions associated low-carbon transitions in the literature



Note: Positive emotions plotted in the upper axis, negative in the lower axis. Colours are arranged in the order they appear in the legend, that is greed at the bottom row, guilt the second bottom, and so on. Desire is the first row for positive emotions, followed by hope, joy, and so on. See methods for more details on inclusion and exclusion criteria for reviewed literature. Note HVPLs = high voltage power lines, CCS = carbon capture and storage, EVs = electric vehicles.

As our findings in Section 5.1 already indicated, a range of emotions are related to energy and transport systems. We see emotions range from the desire to energy access (Ahlborg 2018) or EVs (e.g. Kershaw et al. 2018) to the impact of long-term energy transitions such as the death of the coal industry (e.g. Rohse et al. 2020; Della Bosco and Gillespie 2018; Wright 2018). Within larger-scale energy transitions, related for example to the transition away from coal, initial self-appraisal feelings of *pride* about being part of the coal industry can change to negative event related feelings of *loss* and *sadness*. Energy delivery infrastructure in particular is prone to raising emotions, as Lienert et al. (2015; 2017) outlined in their study of high voltage power lines, concluding that public opposition can emerge if people's emotional bonds with their place are disrupted (see also Brown et al. 2019).

But even smaller and more decentralized energy infrastructures have strong emotions linked to them. For example, distributed resources like solar power usually evoke positive emotions (Perlaviciute et al. 2018). Solar as technology is often installed in community energy projects and small-scale co-operatives, members of which have reported

feeling joy and pride in being involved in such projects (Centgraf 2018; Mälgand et al. 2014). However, feelings of neglect have been reported by some family members of those who have dedicated a lot of time for such projects (Centgraf 2018). Household appliances cause a range of emotions as well, from that of love for age-old cookers to frustration over how much space appliances take or the noise they make (Wright 2018).

5.3 The temporality of expectations and emotional reactions

In addition to the type of emotions and which specific technologies they relate to, we also categorised emotions based on temporality. By this it can be shown how emotions are attached to technologies at very different levels of maturity, readiness, commercialization, and so on. Based on the classification of different transition phases in Section 3, we identified three classes of energy and climate systems in our dataset:

- Those that are newly emerging and not yet fully commercialized, e.g. hydrogen fuel cells and CCS;
- Those that are accelerating and starting to compete with dominant regimes, e.g. community energy, solar, wind, EVs;
- Those that are fully established or even in decline, e.g. nuclear, hydropower, coal, appliances, bikes, and HVPLs.

Based on this clustering, we can reconceptualize emotions by technologies at very different phases of their lifecycle, an overview for which is offered in Table 4.

Table 4: The emotions of low-carbon innovations across the temporal phases of emergence, acceleration and stabilization

	Emerging (hydrogen, CCS)	**Accelerating (community energy, solar, wind, EVs)**	**Stabilized (nuclear, hydropower, coal, appliances, bikes, and HVPLs)**
Positive emotions			
Desire	+	+++	++++
Hope		++	++
Joy	+		+
Gratitude	++	+++	+++++
Pride	+	+++	++
Generosity		+	++
Love			+

Negative emotions			
Fear	++	+++	++++++
Anger	++	++	+++++
Shame		+	
Guilt		+	+
Greed	+	+	

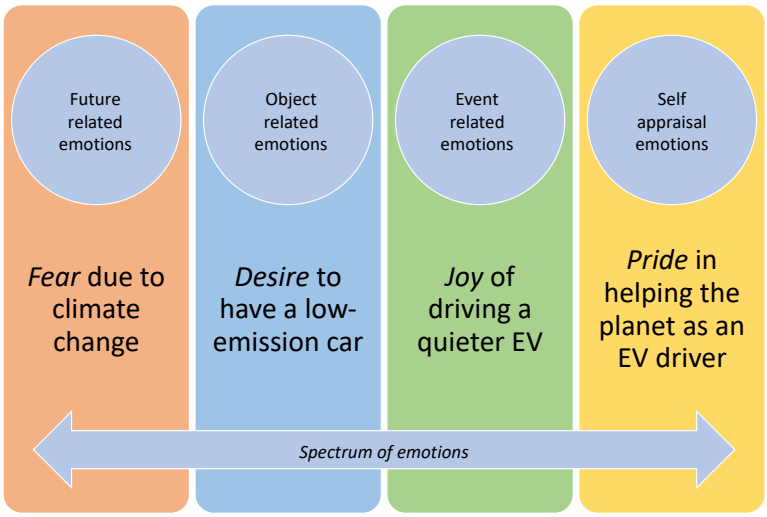
Note: HVPLs = high voltage power lines, CCS = carbon capture and storage, EVs = electric vehicles. The number of + correspond to the number of times a particular technology was affiliated with the emotion.

As Table 4 qualitatively indicates, there are no clear trends in terms of emotions and different phases of low-carbon transitions, which could partly be due to fact that only a limited number of studies have actually focused on examining emotional responses in different transition phases. What is clear, however, is that there is a range of both positive and negative emotions across all phases. Negative emotions feature more than positive ones, but positive feelings like desire remain even for stabilized technologies such as hydropower or coal, or well adopted items such as electrical appliances and bicycles. Also, people still fear and are afraid of these established technologies. That said, some peculiarities do emerge. Shame and guilt do seem to only emerge with the more dominant or becoming domain technologies. Love only occurs with fully established technologies. The intensity of emotions tends to increase as one moves towards stabilization, which could be because more technologies in our sample were stabilized, and therefore likely to have been better known and more the subject to research.

For example, in the case of energy access in Tanzania (Ahlborg 2018), developing better energy infrastructure was driven by the *desire* for a better quality of life, but when the energy development did not materialize quite as expected, event related negative feelings of *frustration*, and negative self-appraisal feelings of *shame* emerged. Similarly, Wright (2018) wrote about people in the UK changing from coal-fired homes to gas and electric homes, giving an example of a woman born in the 1940s who experienced miners' strikes and fuel shortages in the 1970s and had severe guilt over wasting electricity (or other waste) to the point that she developed an eating disorder. Kershaw et al. (2018) too showed with car drivers trialling EVs that their emotions changed over time on one hand, some felt dissatisfaction as the EV did not operate as expected, but on the other hand others were

disappointed having to go back to an ordinary car after the trial. These examples show how emotions are particularly relevant in regards to expectations on specific low-carbon transitions. An example of an emotional spectrum for one individual low-carbon innovation, an EV, is illustrated in Figure 4.

Figure 4: An illustrative spectrum of changing emotions related to driving an EV



Source: Authors. Note that this includes only one emotion per category for illustrative purposes and does not exclude other emotions.

6 Future research: Towards a research agenda for emotions in sustainability transitions

Our analysis recognises that emotions have an integral and important part in the success of sustainability transitions. Given the potential importance of emotions in the low-carbon sustainability transitions we examined here (across energy, transport and mobility, and buildings and housing), our analysis also points the way towards future and potentially fruitful research. This agenda has six concurrent and interconnected branches.

First, we urge the sustainability transitions community to undertake new, empirical research on this topic, by examining different emotions (that go also beyond the Robinson (2008) typology) at different scales, and across a number of relevant actors and stakeholders in sustainability transitions (e.g. innovators, users, policymakers, industry, researchers). This would help complement and triangulate our synthesis of the literature with new, timely, and original data. Often, such exercises challenge the literature and can confirm that many hypotheses held in academic studies are no longer valid when tested

618 with empirical data from consumers or the public, which Sovacool et al. (2012) found to be
619 the case when comparing energy security suppositions in the academic literature with the
620 preferences of citizens.
621 Second, our analysis centred mostly on those emotions or feelings arising from low-
622 carbon transitions, but not sustainability transitions as a whole. Future work could indeed
623 explore the context and extent of such emotions in other empirical areas such as:
624 • Agriculture and food, including food sharing but also emerging options such as meat
625 substitutes or more sustainable genetically modified crops, or livestock rearing;
626 • Fishing and aquaculture, including techniques for ocean protection or marine
627 protected areas, or new innovations such as deep sea mining or ocean fertilization;
628 • The decarbonization of industry and options such as 3D printing, automation, and
629 carbon capture utilization and storage, all which may impinge upon emotions
630 connected to sense of place, geography and new industry;
631 • Telecommunications, digitization, automation and the Internet of Things including
632 5G networks, already producing strong emotions (e.g., fear) for perceived
633 connections (rightly or wrongly) to cancer or even the Covid-19 pandemic;
634 • Other climate protection pathways such as greenhouse gas removal, negative
635 emissions, solar geoengineering and solar radiation management which may require
636 entirely new sociotechnical configurations;
637 • Transitions in urbanization and urban resilience, including how cities and other sub-
638 national actors (such as transport planners, see Panek and, Benediktsson (2017),
639 e.g. respond to natural disasters or emergencies.
640 All of these topics—and indeed myriad ones not mentioned here—would be fruitful to
641 examine alongside the ones covered in our study.
642 Third, emotions may warrant new empirical material, new topical directions, as well
643 as new methods of collecting that data. There is a case to be made for focusing on the
644 phenomenology of emotions (Landweer and Szanto 2020; Sovacool et al. 2020a), that is,
645 approaches centred on phenomenology or the direct lived experiences of particular
646 communities facing sustainability transitions. Such an approach would likely benefit from
647 being grounded in applied anthropology (Smith and High 2017) or ethnography (Hughes et
648 al. 2020), while also considering issues such as the role of values (e.g. Perlaviciute et al.

649 2018). Similarly, research designs could focus on how emotions change via experimental or
650 quasi-experimental designs based on different acts of priming (Carnelley and Row 2010) or
651 framing (Hazboun et al. 2019; Sanderink 2020; Bayulgen and Benegal 2019) certain
652 questions or experiences. These research designs could help determine which emotions
653 have strong resonance (Williams et al. 2019) or resilience (Foster et al. 2014), or require
654 adjustment (Valsaraj et al. 2017), and which do not. Other promising methodological
655 avenues include the use of big data, machine learning, and sentiment analysis, where
656 researchers could look at population level data to determine the prevalence of particular
657 emotions based on keyword searches of social media such as Facebook or Twitter (Müller-
658 Hansen et al. 2020; Sovacool et al. 2020c). Or collecting data from other sources, such as
659 household diaries, oral histories, or even Living Laboratories that can monitor people's
660 emotions (associated with different technologies) in real-time, real-world situations
661 (Sahakian et al. 2021).
662 Fourth, emotions also challenge many existing conceptual frameworks within the
663 field of sustainability transitions. They may for example cut across the niche, regime, and
664 landscape features of the Multi-Level Perspective, or permeate all of the "functions" of the
665 technological innovation systems (TIS) approach. Such frameworks, and others, may need
666 extended, modified, tweaked, enhanced or even reformed to accommodate the potential
667 salience of emotions.
668 Fifth, work on organizational, group or community emotions can complement
669 research on individual emotions. For example, emotions experienced in, or by, groups may
670 be very much different than those experienced by an individual (Coissard et al. 2017) and
671 further research could for example examine the relation between individual and collective
672 level emotions. Our framework may also apply to emotions within organizations and
673 institutions, as well as communal and shared emotions related to low-carbon transitions,
674 e.g. from neighbourhoods and communities (e.g. coal mining, community energy) to whole
675 countries (e.g. energy saving and energy transitions, climate change). Decision about low-
676 carbon sustainability transitions involving energy, transport and buildings are inherently
677 shaped by historical, shared, emotions, which ultimately also influence the acceptance,
678 uptake and success of such transitions. In this light, non-individualistic accounts of emotion
679 (such as practice theory) may become all the more relevant (see e.g. Sahakian and Berthob

2018; Hampton and Adams 2018; Weenink and Spaargaren 2016; Wetherell 2014) in sustainability transitions research.

Sixth and finally, the topic of our research has treated two units of analysis—sustainability transitions, and emotions—as distinct. But in practice, both may coevolve and interrelate with each other. Emotions can change over time but so can technologies (via innovation, improvements in performance, etc.). This may create a sort of "double temporality" to the emotions of transitions, as well as interesting feedback loops that we deserve to be more closely examined. These feedback loops may be similar to the notion of "promise-requirement" cycles in the sociology of expectations (Van Lente 2012), or they may take on entirely new and differentiated dynamics. We would therefore welcome future research on questions such as which emotions could stimulate or constrain acceleration and/or stabilisation, how and under which conditions.

7 Conclusion

We set out to examine, via systematic review of previous literature, whether and how emotions have been explicitly studied in low-carbon sustainability transitions. Our study, although systematic, exploratory and qualitative in nature, highlights that low-carbon sustainability transitions raise a spectrum of emotions and these are not static, but can change over time, from fear and shame to pride and nostalgia. Emotions relating to energy systems for example, can change over a person's lifetime, as well as across different types of energy technology and across different temporal phases of where that technology sits within the sociotechnical regime, though some emotions persist. Nostalgia plays a part, especially in terms of behaviours learnt in childhood (e.g. Wright 2018) and how people cope with changing circumstances such as the death of an industry like coal (Della Bosco and Gillespie 2018; Rohse et al. 2020). For example, the transition from solid fuels like coal to gas and electric heating in the UK provoked strong emotions such as desire and loss (see Wright 2018).

Specific appliances, such as gas cookers, electric blankets, and coal fires (e.g. Wright 2018) have emotional resonance that go beyond their initial functionality. Emotions, however, are not only confined to a person but there are communal and shared emotions related to low-carbon transitions, e.g. from neighbourhoods and communities (e.g. coal

711 mining, community energy) to whole countries (e.g. energy saving and energy transitions,
712 climate change).
713 If one accepts this finding, then the implications of it become potentially profound.
714 First, learning to acknowledge, understand, and integrate emotions related to low-carbon
715 transitions, rather than trying to ignore or suppress them could be a central feature of
716 training for those who design, develop and decide on energy and transport systems (e.g.
717 Rohse et al. 2020; Tejedor and Segalas 2018; Wamsler et al. 2018), be it policymakers,
718 industry, regulators or end-users. Greater emotional literacy from policymakers could in the
719 first place improve collective decision-making and collaboration in government, given the
720 importance of social intelligence communicated via emotions and the importance of
721 creating a safe psychological space for good collaboration (Mair et al. 2019). It could
722 potentially improve the ability of organizations in government to learn, given that if people
723 do not like each other, they are less likely to learn from each other (Mair et al. 2019). It will
724 also be crucial for industry developing new products and services, or large-scale projects.
725 Skills to develop attention management and a more proactive way of dealing with negative
726 emotions can enhance engagement, motivation and productivity both at individual and
727 group levels.
728 Second, understanding and unearthing emotions related to low-carbon transitions
729 are also vital for those successfully adapting new technologies and services. This is
730 particularly key in realizing that new technology may not work like old one and can turn out
731 to be different from what was expected, raising different emotional responses. For example,
732 heat pumps may make different noises from gas boilers, EVs will have a different driving
733 experience to classis cars, and moving to a flexible renewable energy tariff may require
734 using electric appliances at different times.
735 As we transition to a net zero society and require systemic changes in our homes,
736 transport and mobility options, and relevant behaviours, we need to consider emotional
737 responses to such changes – be it from policy makers, industry representatives or
738 householders. Our study is a first step towards developing a research agenda for emotions in
739 sustainability transitions - and recognising that emotions are an inherent part in the success,
740 or unsuccess, of sustainability transitions. We believe this to be a critical topic that deserves
741 far more future attention from both research and policy.
742

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