1   Representing the drivers of lifestyle change in Integrated Assessment Models using theories

2   from environmental psychology: introducing the Motivation, Agency, and Past Behaviour

3   (MAP) framework

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13   Abstract

14   Sustainable lifestyle changes are an important demand-side solution to reduce CO_2 emissions.

15   While sustainable lifestyles are increasingly included in integrated assessment models,

16   modellers have so far not managed to realistically model what drives changes in lifestyles.

17   Important questions about the feasibility and likelihood of lifestyle change, and how lifestyle

18   changes can be accelerated or promoted thus go unanswered. Environmental psychology is a

19   discipline dedicated to understanding environmental behaviour, and its theories and findings

20   could therefore be instrumental to informing the modelling of lifestyle change in integrated

21   assessment models. Yet, we identify two barriers currently hinder the systematic integration

22   of this knowledge into integrated assessment modelling. The first barrier is plurality: there are

23   many theories and findings that are potentially relevant to modelling lifestyle change, but

24   guidance is lacking on which to apply when. The second barrier is ambiguity: many theories

25   in psychology are not precise enough to unambiguously translate them into a mathematical

26   model. To overcome the barrier of plurality, we introduce the Motivation, Agency, and Past

27   behaviour (MAP) framework, which summarises and integrates the insights of 8 prominent

28   behavioural theories used in environmental psychology and that can be used to determine

29   which theories and determinants are most relevant for specific modelling applications. To

30   overcome the barrier of ambiguity, we identify three areas where the precision of theorizing in

31   environmental psychology can be improved, namely definitions and consistent use of

32   constructs, the specification of relationships between constructs, and describing the strength

33   and boundary conditions of these relationships. We urge for closer collaborations between

34   modellers and environmental psychologists to successfully model the drivers and impacts of

35   sustainable lifestyle change.

36   Keywords: lifestyle change, environmental behaviour, IAM, theory, environmental

37   psychology, modelling

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39   from environmental psychology: introducing the Motivation, Agency, and Past Behaviour

40   (MAP) framework

41   Climate change poses a severe and global threat to people and nature (IPCC, 2023).

42   While the consequences of climate change are already unfolding, the worst impacts can still

43   be avoided if climate change is limited to 1.5 or 2 degrees (IPCC, 2018, 2023). Integrated

44   assessment models (IAMs) play a critical role in outlining the pathways that could be taken to

45   reduce greenhouse gas emissions and reach climate targets (see IPCC, 2023). While these

46   models feature highly sophisticated representations of earth systems and economic and

47   societal developments, the dynamics of human behaviour are not systematically represented

48   (Beckage et al., 2021). Yet, changes in behaviour towards more sustainable lifestyles are

49   critical elements in the response to climate change (e.g., Grubler et al., 2018; van Vuuren et

50   al., 2018). Accurately representing such lifestyles changes in IAMs is thus essential to ensure

51   their policy relevance to reach realistic and effective scenarios for combating climate change.

52   The field of environmental psychology has studied the drivers of pro-environmental

53   behaviour for over 40 years (e.g., Cone & Hayes, 1984; Stokols, 1978), and therefore

54   represents a rich resource to inform the modelling of sustainable lifestyle changes. Yet, this

55   literature has so far not been systematically applied in integrated assessment modelling. The

56   aim of this paper is therefore to showcase what the environmental psychology literature can

57   contribute to the climate modelling community, and to examine how its uptake in IAMs can

58   be accelerated. We start by reviewing the current state of the art regarding the representation

59   of human behaviour in IAMs. We then identify two barriers to effectively using the

60   environmental psychology literature (and social science literature more generally) to model

61   drivers of lifestyle changes. The first barrier is plurality: there are many potentially relevant

62   theories and findings, making it difficult to decide what to include in IAMs. The second

63 barrier is ambiguity: many theories are not precise enough to unambiguously translate them

64 into a mathematical model. We then introduce solutions to overcome these barriers for the

65 environmental psychology literature, specifically. To overcome the barrier of plurality, we

66 introduce the MAP-framework (Motivation, Agency, Past Behaviour): a meta-theoretical

67 framework that summarises and integrates the key insights from 8 important theories in

68 environmental psychology, and which can be used to determine which theories and

69 determinants are most relevant for specific modelling applications. We illustrate the usage of

70 the MAP-framework with a case study that focuses on electric vehicle adoption. To overcome

71 the barrier of ambiguity, we introduce a comprehensive research agenda that identifies key

72 areas in which the precision of theories in environmental psychology can be improved.

73

74 **Representing lifestyle change in IAMs**

75   IAMs play a key role in climate science, discourse, and policy. Featuring sophisticated

76 simulations of natural processes and economic and societal developments, they can be used to

77 explore how different policies affect global CO_2 emissions, temperature levels, and economic

78 outcomes (see Riahi et al., 2017). So far, IAMs have mainly focused on so-called supply-side

79 solutions: solutions that aim to reduce greenhouse gas (GHG) emissions by either making the

80 supply of energy more sustainable and more efficient, mostly via technological advances such

81 as renewable and nuclear energy, or by removing emitted carbon from the atmosphere

82 through carbon capture and storage (Creutzig et al., 2021; Mundaca et al., 2018). Supply-side

83 solutions alone will however likely not be sufficient to reach the goal of limiting global

84 warming to 1.5 degrees (Cap et al., 2024), while the feasibility of scaling up carbon capture

85 and storage is also debated (Dziejarski et al., 2023; Kriegler et al., 2018).

86   In addition to supply-side solutions, more and more attention is therefore now being paid

87 to the potential of demand-side solutions, which aim to reduce GHG emissions by lowering

88   the demand for energy, goods and services by households, institutions, and businesses

89   (Creutzig et al., 2021; Creutzig et al., 2024; Grubler et al., 2018; van Vuuren et al., 2018).

90   Demand-side solutions can, if supplemented with infrastructural and technological changes,

91   substantially reduce GHG emissions in different end-use sectors, from 40% in the food

92   domain, to 73% in the electricity domain (IPCC, 2023). Interestingly, demand-side solutions

93   can in many cases also contribute to increasing well-being, for example by reducing pollution

94   and increasing health (Creutzig et al., 2021; Mundaca et al., 2018).

95   Many demand-side solutions require changes in people's lifestyles, including the way

96   in which people travel, eat, use energy, and buy, use, and dispose of products (van den Berg et

97   al., 2019). Sustainable lifestyle changes are, in the context of integrated assessment

98   modelling, defined as changes in people's behaviour that lower the demand for energy in the

99   broad sense of the word, and thus have a positive impact on the environment (van den Berg et

100   al., 2019). While lifestyle changes are increasingly included in IAMs, they are currently often

101   modelled exogenously as fixed assumptions, meaning they are assumed to be adopted by

102   people universally, and without considering their feasibility and likelihood, nor how they

103   could be affected by other developments that form part of the model, such as changes in the

104   climate, implemented policies, or technology changes (see Figure 1) (Napp et al., 2019;

105   Pettifor et al., 2023; Samadi et al., 2017; Saujot et al., 2020; Trutnevyte et al., 2019; van den

106   Berg et al., 2019).

107   While exogenously modelling lifestyle change provides important insights into the

108   potential of lifestyle change as a strategy to reduce GHG emissions, such models rely on the

109   assumption that lifestyle changes will occur spontaneously (Saujot et al., 2020; Trutnevyte et

110   al., 2019). Yet, decades of social science research demonstrate that behaviour change can be

111   difficult to realise (e.g., Duckworth & Gross, 2020). Key questions regarding the feasibility

112   and likelihood of lifestyle change as a demand-side solution thus currently go unanswered

113   (Otto et al., 2020). For example, to what extent are people willing to change their lifestyle,

114   and which behaviours that are part of lifestyle changes are they more or less likely to adopt?

115   Who are most open to change their lifestyles, who are least likely to change? Which factors

116   affect the motivation and ability to change lifestyles? How quickly can changes in behaviour

117   occur across social groups and under which conditions or policies is behaviour change more

118   or less likely? In current modelling representations, lifestyle change thus remains a black box

119   (Figure 1).

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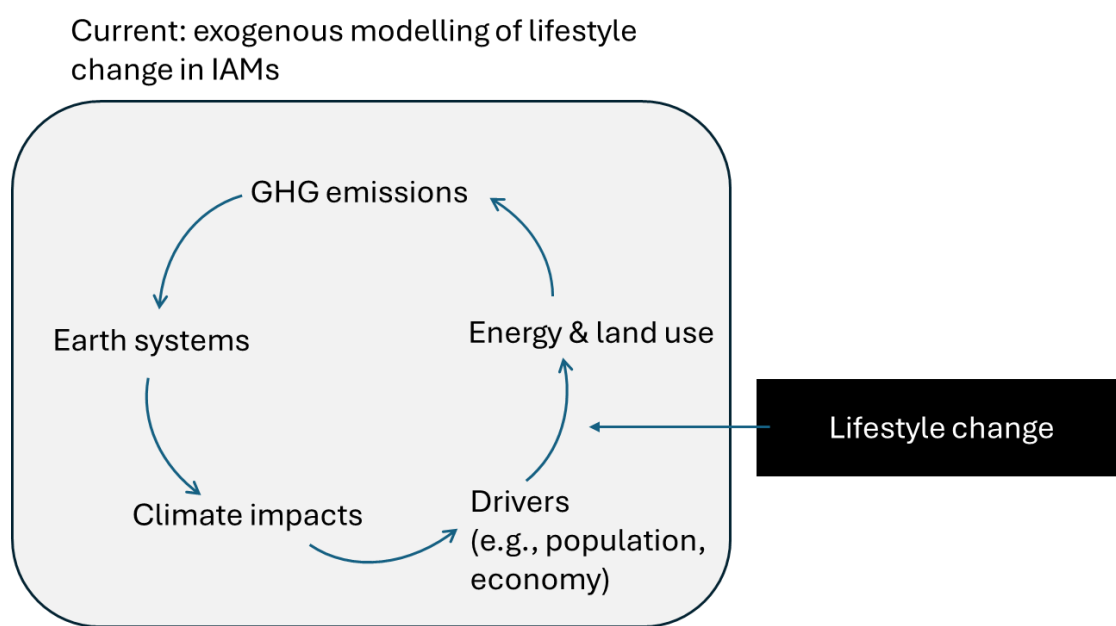
121   Figure 1. Simplified representation of the current exogenous modelling of lifestyle changes in
122   IAMs.

123

124   To explore these questions and increase the behavioural realism of lifestyle change,

125   IAMs will need to endogenously model lifestyle changes, meaning they explicitly consider

126   the factors that affect the likelihood of lifestyle changes, or changes in people's environmental

127   behaviours, and link them to other elements represented in IAMs (see Figure 2) (Samadi et

128   al., 2017; van den Berg et al., 2019). Here, environmental psychology comes in as a relevant

129   body of knowledge. Since at least the 1970s, environmental psychologists have studied

130   environmental behaviour (e.g., Cone & Hayes, 1984; Stokols, 1978), which is defined as

131   'behaviour that change the availability of materials or energy from the environment or alter

132   the structure and dynamics of ecosystems or the biosphere' (Steg & Vlek, 2009). More

133   specifically, environmental psychologists are interested in what motivates people to engage in

134   pro-environmental behaviour, or 'behaviour that harms the environment as little as possible,

135   or even benefits the environment' (Steg & Vlek, 2009, p. 309), which conceptually aligns

136   with sustainable lifestyle change. Indeed, virtually all behaviours that are considered relevant

137   as part of a sustainable lifestyle, such as lowering the thermostat, traveling more sustainably,

138   and eating a sustainable diet (e.g., see Eker et al., 2019; Grubler et al., 2018; McCollum et al.,

139   2017) are (and have been) studied in the domain of environmental psychology (Hampton &

140   Whitmarsh, 2023). Indeed, as we will show below, decades of work in this field have led to

141   comprehensive insights into the factors that are relevant to understanding pro-environmental

142   behaviour in general (see for example Bamberg & Möser, 2007; Klöckner, 2013; Steg et al.,

143   2014), as well as specific types of pro-environmental behaviour (e.g., Gardner & Abraham,

144   2008; Geiger et al., 2019; Graves & Roelich, 2021).
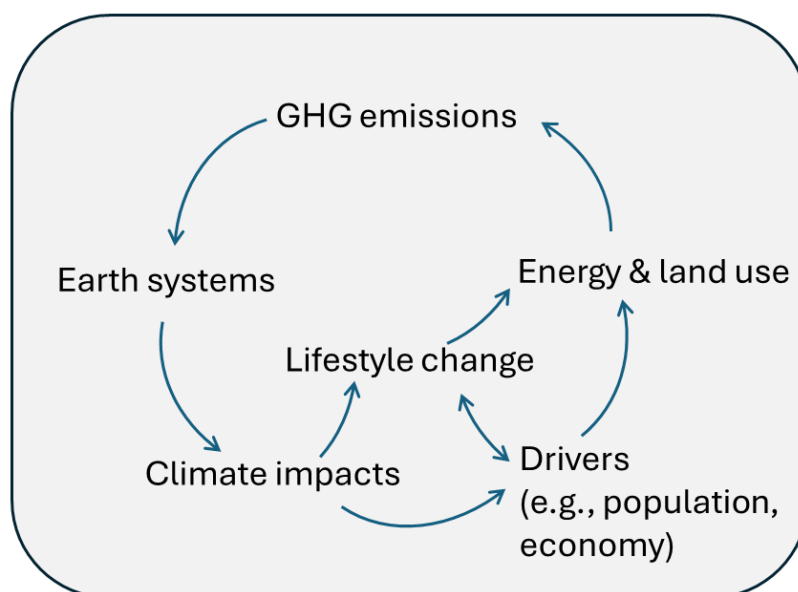

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146 Figure 2. Simplified representation of the desired endogenous modelling of lifestyle changes

147 in IAMs.

148   Some initial studies already show that explicitly modelling the drivers of

149 environmental behaviour using insights from environmental psychology can yield insights

150 into if and under which conditions lifestyle changes can be achieved (see for example

151 Beckage et al., 2018; Eker et al., 2019; McCollum et al., 2017; Moore et al., 2022). For

152 example, a study that modelled the drivers of sustainable food consumption found that a

153 significant global shift towards more sustainable consumption patterns was unlikely to occur

154 without policy interventions (Eker et al., 2019). Moreover, particularly people's perceived

155 self-efficacy (i.e., perceptions of being able to engage in the behaviour) and social norms (i.e.,

156 perceptions which behaviour is commonly done and approved of by others), rather than

157 concerns about health or perceived risks of climate change, were key in realizing the societal

158 shift to a more sustainable diet (Eker et al., 2019). Such insights are critical to developing

159 effective interventions that target the relevant determinants of behaviour (see van Valkengoed

160 et al., 2022), demonstrating why modelling specifically the drivers of environmental

161 behaviour is so important.

162 **Barriers to modelling sustainable lifestyle changes**

163   At first glance, the environmental psychology literature thus seems perfectly suited to

164 help modellers overcome the challenge of endogenously modelling of sustainable lifestyle

165 changes in IAMs. Yet, despite a rich body of literature to build on and promising initial

166 efforts, works that endogenously model sustainable lifestyle changes have been rare, and

167 environmental psychology literature and findings have so far been represented in models to

168 only a limited extent. While we currently have a handful of proof-of-concept studies (Beckage

169 et al., 2018; Bury et al., 2019; Eker et al., 2019; McCollum et al., 2017; Moore et al., 2022),

170 there is no consistent or dedicated stream of literature that considers how the modelling of

171   lifestyle changes can be further refined, that challenges or expands upon previous models, that

172   considers which methods are most appropriate to capture behavioural dynamics, that

173   synthesizes the best practices and challenges in the literature, or that discusses how the

174   different theories and vast body of empirical findings in environmental psychology can be

175   best applied.

176   The mere availability of a large literature on the drivers and barriers of pro-

177   environmental behaviour therefore does not suffice to address the challenge of more

178   systematically considering lifestyle changes in IAMs. We identify two barriers that currently

179   hinder systematically applying insights from environmental psychology (but which broadly

180   also apply to other bodies of social science literature that study environmental behaviour).

181   The first barrier is that there is a large number of theories and findings that could be

182   potentially relevant to modelling the drivers of environmental behaviour, and it is therefore

183   difficult to determine which factors and theories to focus on (see also Elsawah et al., 2020;

184   Müller-Hansen et al., 2017; Schlüter et al., 2017). We call this the barrier of plurality. Imagine

185   you want to model factors influencing the adoption of a sustainable diet (see (Eker et al.,

186   2019), for practical application). Various theories employed in environmental psychology

187   could explain dietary choices, such as Protection Motivation Theory (Rogers, 1983), which

188   proposes that behaviour depends on perception of risk sand perceived efficacy and costs of

189   behaviours, Value-Belief-Norm Theory (Stern, 2000), which focuses on people's moral

190   motivations to engage in behaviour, or the social identity approach (Abrams & Hogg, 1990)

191   which particularly considers social reasons why people may or may not follow a vegetarian or

192   vegan diet. The difference between theories, their explanatory scope, and the conditions under

193   which particular theories perform better or worse in explaining particular behaviours, are

194   often not clearly outlined in the descriptions of the theories, which can make it difficult to

195   make an informed choice.

196   The second barrier is that many theories in environmental psychology (and beyond)

197   are not yet precise enough to unambiguously translate them into mathematical expressions,

198   which is needed to be able to integrate psychological theories into a model (De Cian et al.,

199   2020; Poile & Safayeni, 2016; Schlüter et al., 2017; Schwarz et al., 2020; van Sluisveld et al.,

200   2020). For example, theories often do not specify the strength or shape (e.g., linear, parabolic,

201   sigmoidal) of relationships between predictors of behaviour, or how these relationships

202   develop over time (Elsawah et al., 2020). As a result, researchers need to decide how they will

203   translate the verbal description of a theory into mathematical equations, but such assumptions

204   are currently difficult to determine and justify. Different modelling teams may thus interpret

205   and implement the same theories in different ways, making it difficult to compare different

206   modelling implementations to each other, and to determine which implementations are either

207   more or less accurate, which hinders the cumulative improvement of modelling the drivers of

208   environmental behaviour (Muelder & Filatova, 2018). We call this the barrier of ambiguity.

209   We propose two solutions to these barriers that will help make better use of the

210   environmental psychology literature to represent the drivers of environmental behaviour in

211   IAMs. First, to overcome the barrier of plurality, we introduce the Motivation, Agency, Past

212   behaviour (MAP) framework, a meta-theoretical framework that summarizes and synthesizes

213   insights from eight main behavioural theories in environmental psychology. This framework

214   summarizes the key theorizing in environmental psychology, and enables researchers to

215   identify and select relevant theories or determinants of environmental behaviour and

216   lifestyles. Second, to overcome the barrier of ambiguity, we identify in what areas theorizing

217   in environmental psychology lacks specificity, and suggest guidelines on how theorizing can

218   be made more precise such that theories can be formalized (or rendered mathematically)

219   within models with less ambiguity and uncertainty. A visual overview of the barriers and

220   solutions is presented in Figure 3.
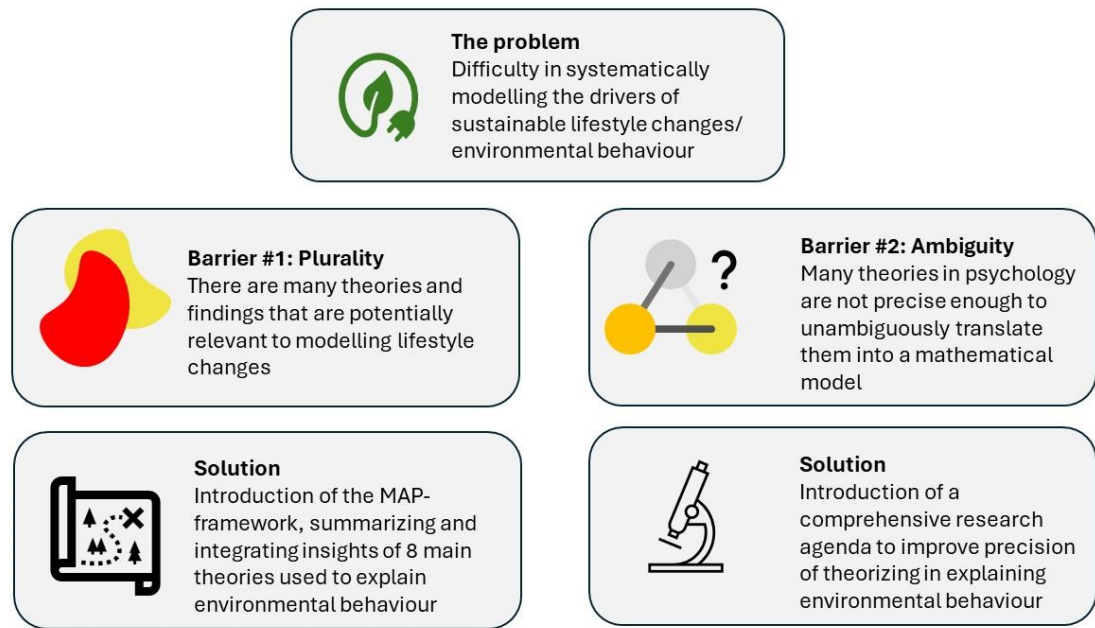
221

222 Figure 3. Visual overview of the main problem, key barriers, and proposed solutions.

223 **Overcoming the barrier of plurality: the MAP-framework**

224   Within environmental psychology, there is a large body of theoretical and empirical

225 literature on the determinants of environmental behaviour (e.g., Bamberg & Möser, 2007;

226 IPCC, 2018; Klöckner, 2013; Steg, 2023). One way to cope with the plurality of theories is to

227 develop a meta-theory: higher-order theorizing that analyses, structures, and compares

228 different theories (APA, 2018a). Such meta-theory can be used to make an informed decision

229 on which theory or which constructs to model, when, and why, thus helping the development

230 of focused and concise models.

231   We introduce here a new meta-theoretical framework based on the most relevant

232 theories in environmental psychology used to explain environmental behaviour, which

233 outlines differences and overlaps between theories (see Figure 4). We call this meta-theory

234 the MAP-framework (*Motivations, Agency, Past behaviour*). To develop the MAP-

235 framework, we first determined, on the basis of literature reviews on pro-environmental

236 behaviour and text books on environmental psychology (Bamberg & Möser, 2007; Dietz,

237 2023; Gifford & Nilsson, 2014; Gifford et al., 2011; Klöckner, 2013, 2015; Koger & Du Nann

238 Winter, 2010; Scott et al., 2021; Steg & Nordlund, 2018; Steg & Vlek, 2009; Turuga et al.,

239 2010; van Valkengoed et al., 2022; White et al., 2019), the most important theories used to

240 explain environmental behaviour in the field, which are:

241   1.   Theory of Planned Behaviour (Ajzen, 1991)

242   2.   Protection Motivation Theory (Rogers, 1983)

243   3.   Norm Activation Model (Schwartz, 1977)

244   4.   Value-Belief-Norm Theory (Stern, 2000)

245   5.   Environmental Self-Identity Theory (Van der Werff et al., 2013)

246   6.   Focus Theory of Normative Conduct (Cialdini et al., 1990)

247   7.   The Social Identity Approach[1] (Abrams & Hogg, 1990)

248   8.   Habit Theory (Orbell & Verplanken, 2020)

249   A visual summary of each theory is presented in the Supplemental Material. We

250 organise the insights and propositions of these theories along three main pillars (following

251 Triandis, 1977). First, what motivations do people have to (not) engage in pro-environmental

252 behaviour? Second, to what extent do people feel agency to engage in pro-environmental

253 behaviour and reduce their environmental impact? Third, how does past environmental

254 behaviour influence future pro-environmental behaviour? Importantly, we point out that the

255 same or similar constructs appear in different theories under different names. To avoid

256 confusion, we refer here to the same constructs across different theories using one single label

257 following the overview of relevant constructs used to explain environmental behaviour

258 provided in (van Valkengoed et al., 2022), while providing the label originally used in the

259 theory between brackets and in cursive. We discuss this problem of inconsistent labelling of

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[1] The Social Identity Approach is strictly speaking not one distinct theory, but refers to the integrated insights from self-categorization theory (Turner, 1987) and social identity theory (Tajfel & Turner, 1986). We refer to the Social Identity Approach in this paper as we review constructs and ideas from both self-categorization and social identity theory.

260   constructs in more detail later. The following section introduces the main ideas of these 8

261   theories, and presents a comprehensive overview of key theorizing within environmental

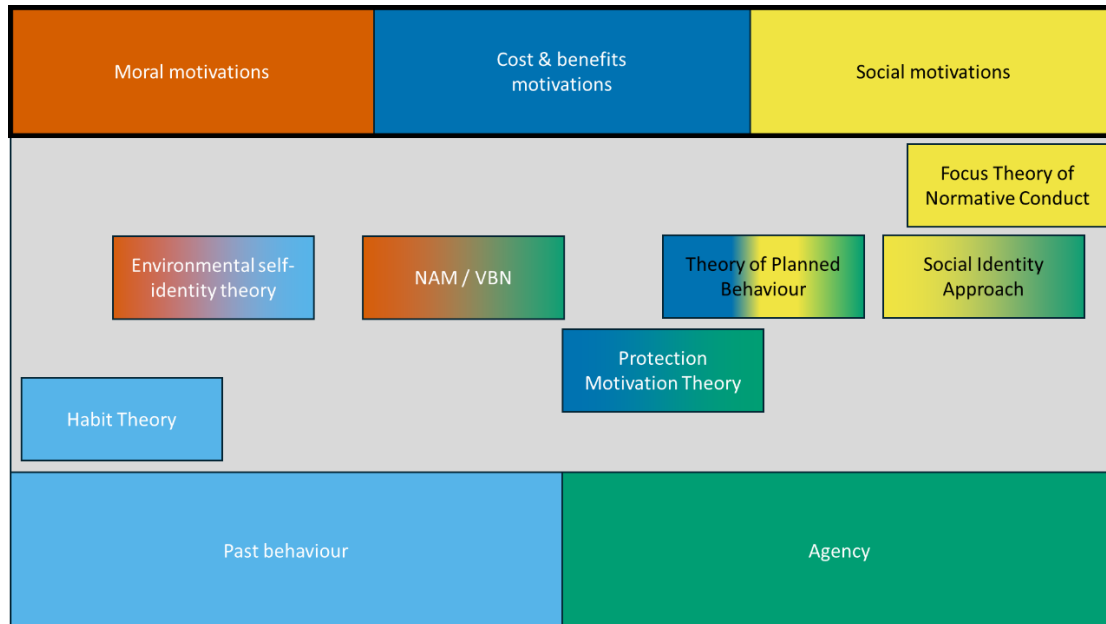262   psychology.

263

264   Figure 4. Schematic overview of the MAP-framework, which showcases how 8 major

265   theories used to explain environmental behaviour in environmental psychology fit into this

266   framework, and how these theories overlap and differ from each other. NAM = Norm

267   Activation Model. VBN = Value-Belief-Norm Theory.

268

269   *What motivations do people have to (not) engage in pro-environmental behaviour?*

270   Motivation can be defined as 'the impetus that gives purpose or direction to behaviour'

271   (APA, 2018b), or more simply, the reasons people have for (not) engaging in behaviour.

272   Across the theories, different motivational factors are identified, which can be summarized

273   into three overarching types of motivation to engage in environmental behaviour: perceived

274   personal costs and benefits, moral motivations, and social motivations (IPCC, 2022). Notably,

275   the theories we included focus mostly on cognitions, or the contents of people's thoughts, to

276   represent people's motivations. However, recent developments in the field demonstrate that

277   many of these motivations are not just cognitive, but are also accompanied by emotions,

278   which can steer people to (not) act pro-environmentally (Brosch, 2021; Brosch & Steg, 2021).

279   Below, we therefore highlight both cognitions as well as relevant emotions that can be

280   associated with each of the motivations.

281   First, perceived **personal costs and benefits** refer to people's evaluations of what they

282   can personally gain from acting pro-environmentally, which are offset against potential

283   personal losses or discomforts (IPCC, 2018; Steg & Vlek, 2009). For example, turning down

284   the heater may save people money (benefit) but may make people feel cold (costs). Costs and

285   benefits can be cognitive evaluations of resources (e.g., time, money), but also affective

286   (feeling good or comfortable, enjoying a behaviour). People's evaluations of the sum of costs

287   and benefits reflect their attitude towards a particular behaviour, which is a key construct in

288   the Theory of Planned Behaviour (Ajzen, 1991). Similarly, Protection Motivation Theory

289   considers trade-offs between costs and benefits as part of the threat appraisal (Rogers, 1983),

290   where costs are conceptualized as perceived risks, which is based on the perceived likelihood

291   and severity of experiencing a hazard. Perception of a risk can be accompanied by emotions

292   such as worry, concern, or fear (van der Linden, 2017). Protection Motivation Theory also

293   proposes that people's motivation to act depends on the perceived rewards associated with not

294   acting pro-environmentally (e.g., being more comfortable), which are referred to as

295   maladaptive response rewards, and the perceived response costs associated with acting pro-

296   environmentally (e.g., the amount of effort required): people are more likely to act pro-

297   environmentally if response costs and maladaptive response rewards are perceived as low

298   (Kothe et al., 2020; Rogers, 1983).

299   Second, people can be driven to act pro-environmentally because of **moral**

300   **motivations,** or in other words, because they believe it is the right thing to do. Both the Norm

301   Activation Model (Schwartz, 1977) and Value-Belief-Norm Theory (Stern, 2000) focus on

302   moral motivations to explain pro-environmental behaviour. The Norm Activation Model

303   proposes that people are more likely to act pro-environmentally when they feel a personal

304   norm to act pro-environmentally, meaning they feel responsible and morally obliged to act in

305   an environmentally friendly way (e.g., Schwartz, 1977). Personal norms are stronger when

306   people are more aware that their own behaviour is causing environmental problems (i.e.,

307   problem awareness, also referred to as *awareness of consequences*), and when they more

308   strongly believe their personal actions will help in resolving the problem (i.e., outcome

309   efficacy, also referred to, perhaps confusingly, as ascription of responsibility within NAM and

310   VBN; see Steg & de Groot, 2010). Outcome efficacy falls under the second pillar of the

311   MAP-framework: Agency, explained below.

312   The Value-Belief-Norm Theory adds to this reasoning that this process of problem

313   awareness, outcome efficacy, and personal norms depends on the extent to which people

314   endorse different values. Specifically, the more people value nature and the environment (i.e.,

315   biospheric values), and find protecting and taking care of other people important (i.e.,

316   altruistic values), the more likely they will have a higher problem awareness, leading to

317   stronger perceptions of outcome efficacy and a stronger personal norm to act

318   environmentally-friendly. Conversely if people have strong egoistic and hedonic values,

319   meaning they strongly value personal resources (e.g., money, status) and enjoyment and

320   pleasure, respectively, people will likely have lower problem awareness, and thus lower

321   perceived outcome efficacy and weaker personal norms to act pro-environmentally.

322   Emotions play an important role in explaining why personal norms can influence our

323   behaviour. Specifically, acting in line with personal norms may elicit positive emotions such

324   as pride, while failing to act according to personal norms can lead to negative emotions such

325   as guilt and regret (Onwezen et al., 2013; Shipley & van Riper, 2022). The anticipation of

326   feeling these positive or negative emotions plays an important role in whether people decide

327   to act in line with their personal norms, and thus act pro-environmentally or not (Brosch &

328   Steg, 2021; Schneider et al., 2017).

329   Environmental Self-identity Theory (Van der Werff et al., 2013) proposes that another

330   motivation to act pro-environmentally is people's perception of the extent to which they are

331   an environmentally-friendly person (i.e., environmental self-identity). Environmental self-

332   identity can play an important role in determining environmental behaviour, as people are

333   motivated to act in line with how they see themselves (Festinger, 1957). We consider

334   environmental self-identity as a form of moral motivation, as Environmental Self-Identity

335   Theory proposes that environmental self-identity is rooted in and inferred from people's

336   biospheric values: the more people endorse biospheric values, the stronger their

337   environmental self-identity (Van der Werff et al., 2013).

338   Third, **social motivations** can play an important role in motivating pro-environmental

339   behaviour. In general, people are motivated to be liked and accepted by others and to fit in

340   (Cialdini et al., 1990). The Focus Theory of Normative Conduct proposes that people tend to

341   conform to how they see other people act (the extent to which they think a behaviour is

342   common, also known as the perceived descriptive norm), and to how they think others expect

343   them to act (the extent to which a behaviour is (dis)approved of by others, or the perceived

344   injunctive norm; Cialdini et al., 1990). Perceived injunctive norms are also included in the

345   Theory of Planned Behaviour as a determinant of behaviour (referred to as *perceived*

346   *subjective norm)*. Adhering to or violating descriptive and injunctive social norms can be

347   associated with positive emotions (feeling content, belonging) and negative emotions

348   (shame), respectively (Packard & Schultz, 2023).

349   In addition, a part of people's identity is formed by the social groups they identify

350   with, such as nationality, sports groups, a community, or their political affiliation, which is

351   referred to as people's social identity (Tajfel & Turner, 1986). The Social Identity Approach

352   proposes that if people strongly identify with a particular group, they will be motivated to act

353   in line with and internalise the values and goals of these groups and their members, which

354   affects the likelihood that people act pro-environmentally (Fritsche et al., 2017). Specifically,

355   if acting pro-environmentally is an important value or goal for a specific group, people who

356   are associated and/or identify with this group will act more pro-environmentally themselves

357   (Fielding & Hornsey, 2016).

358   *To what extent do people feel agency to engage in pro-environmental behaviour and to*

359   *reduce their environmental impact?*

360   People's behaviour is not only determined by their motivations. People also need to

361   feel they are be able to act upon their motivations and to reach their goals, which is defined as

362   a sense of agency (Schlosser, 2015). Across the eight behavioural theories, three main factors

363   reflecting this sense of agency are identified: self-efficacy, outcome efficacy, and collective

364   efficacy.

365   First, self-efficacy (referred to as *perceived behavioural control* in the Theory of

366   Planned Behaviour) refers to the extent to which people perceive themselves as capable of

367   engaging in a specific behaviour (Ajzen, 1991). Self-efficacy depends on contextual factors

368   that make it easier or harder (or even impossible) to perform the behaviour, such as available

369   infrastructure, income, but also policy measures, such as laws or financial policies that hinder

370   or promote particular behaviours (Steg & Vlek, 2009). Self-efficacy also depends on

371   psychological factors, such as knowledge about how to perform the behaviour, or confidence

372   in one's own abilities. Both the Theory of Planned Behaviour and Protection Motivation

373   Theory propose that self-efficacy is a key determinant of environmental behaviour: the more

374   people perceive themselves as capable of acting, the more likely they are to do so (Ajzen,

375   1991; Rogers, 1983).

376   Second, agency is determined by the perceived effectiveness or impact of one's

377 behaviour in reducing environmental problems, which is referred to as perceived outcome

378 efficacy (referred to as *ascription of responsibility* in VBN and NAM, *response efficacy* in

379 PMT, sometimes referred to as *outcome expectancy* in other literature). Protection Motivation

380 Theory, the Norm Activation Model, and Value-Belief-Norm Theory identify outcome

381 efficacy as an important determinant of pro-environmental behaviour: the more people

382 perceive pro-environmental behaviour as effective in reducing environmental problems, the

383 more likely they are to engage in it (Rogers, 1983; Schwartz, 1977; Stern, 2000). Even if

384 people perceive they can engage in a pro-environmental behaviour (i.e., high self-efficacy),

385 they may still not engage in it if they perceive these actions as ineffective or contributing little

386 to protecting the environment. Similar to self-efficacy, perceived outcome efficacy can

387 depend on contextual factors (e.g., some behaviours objectively reduce more CO_2 emissions

388 than others), but also on people's subjective evaluations (e.g., personal pro-environmental

389 behaviour may feel futile in the face of pollution by large companies) (Gregersen et al., 2021).

390   Third, the Social Identity Approach identifies perceived collective efficacy as an

391 important factor that can determine people's sense of agency (Mummendey et al., 1999; van

392 Zomeren et al., 2008). Collective efficacy is defined as people's perceptions of whether the

393 group they belong to is capable of reaching their goals through collective effort (e.g.,

394 Mummendey et al., 1999). In the context of environmental behaviour, it has been found that

395 individuals are more strongly motivated to act pro-environmentally if they perceive higher

396 collective efficacy (i.e., they perceive they can, as a group, have an impact and can

397 meaningfully contribute to reducing environmental problems; Fritsche et al., 2017).

398

399   *To what extent does past environmental behaviour influence future pro-environmental*

400   *behaviour?*

401   Next, people's pro-environmental behaviour is affected by their past behaviour.

402 Specifically, people are more likely to act pro-environmentally if they did so in the past as

403 well. Theories have proposed different pathways through which past pro-environmental

404 behaviour can motivate future pro-environmental behaviour: First, Environmental Self-

405 identity Theory (Van der Werff et al., 2013) proposes that past behaviour can influence pro-

406 environmental behaviour via environmental self-identity: if people reflect on the extent to

407 which they have engaged in pro-environmental in the past, they may realise they are a more

408 (or less) of a pro-environmental person than they previously thought. In other words, people

409 can partly infer their environmental self-identity through their past actions, which then affects

410 the motivation to engage in subsequent pro-environmental behaviour (Van der Werff et al.,

411 2013).

412   Second, Habit Theory (Orbell & Verplanken, 2020) proposes that past behaviour can

413 play an important role in determining environmental behaviour when people have formed

414 habits. Habits are tendencies people develop to automatically and without thinking engage in

415 a particular behaviour when they find themselves in a certain context or situation (also

416 referred to as the contextual cue, see Klöckner & Verplanken, 2019). Habits are built up when

417 a particular behaviour is effective at reaching a particular goal, and people therefore engage in

418 the same behaviour in the same or similar setting many times (e.g., turning the lights off when

419 leaving the room) (Linder et al., 2022). People typically do not think or plan to engage in

420 habits, because the action becomes associated or linked to specific cues in the environment

421 (Klöckner & Verplanken, 2019). Unsustainable habits can form a barrier to switching towards

422 more pro-environmental behaviour, because they influence behaviour without conscious

423 decision making (Linder et al., 2022). At the same time, if people engage in a new pro-

424 environmental behaviour often enough and with satisfying outcomes, new habits can form,

425 which ensure that the behaviour will be maintained over time without the need for conscious

426 effort (Lally et al., 2009).

427

428 *How to use the MAP-framework to identify relevant drivers of environmental behaviour for*

429 *inclusion in models*

430   The MAP-framework integrates current theorizing in environmental psychology on

431 the drivers of environmental behaviour, and structures this theorizing by identifying

432 overarching categories of determinants across theories. The MAP-framework can thus help in

433 overcoming barrier of plurality by guiding researchers towards a specific theory or set of

434 determinants that are most relevant to the specific behaviour or lifestyle to be modelled. To

435 this end, the MAP-framework can be used in one of two ways.

436   First, working with one specific theory can guide the development of a concise model

437 as each theory consists of a limited set of constructs. The MAP-framework can be used to

438 differentiate between and select one of the eight underlying behavioural theories we have

439 discussed. Figure 4 illustrates how each theory is situated within the MAP-framework (a more

440 detailed overview that also outlines the individual determinants within each theory is

441 presented in the Supplemental Material). Each theory has a particular focus that may be more

442 or less relevant to modelling a given behaviours. For example, theories focussing on social

443 motivations (Focus Theory of Normative Conduct, Social Identity Approach) may be

444 particularly relevant to explaining behaviours that occur in social setting, such as eating

445 behaviour (Higgs & Thomas, 2016). Theories that focus on moral motivations (e.g., Value-

446 Belief-Norm Theory, Norm Activation Model) may be more relevant to explaining behaviour

447 that requires forgoing personal gains for collective goals, that occurs in private or for which

448 strong social norms do not (yet) exist. To further facilitate selecting a relevant theory for

449 specific modelling goals, we present an overview of the main aims of each theory and

450 suggestions for modelling applications in Table 1. An overview of all the constructs within

451 each theory, and how these are positioned within the MAP-framework, is provided in

452 Supplementary Table 1. A case study that demonstrates how the MAP-framework can be used

453 in practice to select a relevant theory is presented in Box 1.

454   Second, instead of focussing on a single theory, researchers can choose to focus on

455 modelling one of the overarching meta-theoretical pillars, that is, motivations, agency, or past

456 behaviour. This approach may be particularly suited if there is evidence that one of these

457 pillars is particularly important for the behaviour in question, or to explore research questions

458 on how different determinants may interact. For example, modelling *motivations* can offer

459 insight into which type of motivations (i.e., perceived costs and benefits, moral motivations,

460 social motivations) are more or less important for different pro-environmental behaviours,

461 how different motivations may conflict or interact in determining people's pro-environmental

462 behaviour, and whether policies that target specific motivations can be effective in promoting

463 behaviour. A focus on agency can be useful to explore under which conditions people feel

464 empowered to act, and how different policies can influence this sense of agency. Focusing on

465 past behaviour can help to gain insight into the potential speed and difficulty with which

466 behavioural changes can be realised, as strong environmentally unfriendly habits can form a

467 key barrier to behaviour change that need to be weakened before new behaviours can take

468 hold (Linder et al., 2022). Working within each of these pillars further offers the opportunity

469 to explore how constructs from different theories are related to each other. Specifically,

470 because empirical studies within environmental psychology mostly focus on the relationships

471 between variables within the same theory, exploring how constructs from different theories

472 are related represents an opportunity to advance current theorizing and explore possible

473 synergies and integration between theories.

Box 1: Selecting relevant theory to model drivers of lifestyle change using the MAP-framework: The case of electric vehicle adoption

In this case study, we will demonstrate the practical application of the MAP-framework to determine which theoretical framework is most appropriate to model a particular behaviour. We break down this process into 4 steps.

Step 1: Determine target behaviour

Modelling the drivers of lifestyle change starts with determining which behaviour(s) should be represented in the model. A relevant starting point can be to select behaviour(s) with a large potential for emission reductions (Steg & Vlek, 2009). Studies demonstrate that switching from petrol to electric vehicles can reduce per capita carbon emissions by 500 - 2000 kg per year (Ivanova et al., 2020; Koide et al., 2021), making it one of the most promising areas where reductions in carbon emissions can be realized.

Step 2: Determine the drivers and barriers of the target behaviour

We can determine the drivers and barriers of the adoption of electric vehicles by examining literature reviews and meta-analyses. Here, we focus on two literature reviews (Gerber Machado et al., 2023; Pamidimukkala et al., 2024), that respectively review the results of 124 and 537 articles. Table 2 provides an overview of the determinants that are related to the adoption of electric vehicles as listed in these review articles. Both reviews list a wide array of relevant determinants, demonstrating the plurality of relevant research findings researchers may encounter when reading overviews of the literature.

Table 2. Overview of determinants of electric vehicle adoption extracted from literature reviews

(Gerber Machado et al., 2023)	(Pamidimukkala et al., 2024)

1. Purchase price 2. Operational costs 3. Purchase price discount 4. Location/availability of charging stations 5. Charging time 6. Aesthetics 7. Incentives (subsidies, tax exemption/discounts, rebates, lane access, parking) 8. Attitudes 9. Subjective norms 10. Perceived behavioural control 11. Environmental protection concerns 12. Environmental knowledge 13. Risk attitude 14. Low pollutant emissions 15. Socio-demographic variables (e.g., age, gender) 16. Greenhouse gas emission reduction 17. Reduced noise 18. Time required to charge EV 19. Charging capability 20. Availability of charging station 21. Charging fee 22. Speed 23. Range 24. Power 25. Fuel efficiency 26. Battery capacity 27. Vehicle age 28. Acceleration	1. Insufficient number of charging stations 2. Lack of adequate staff at charging/service stations 3. Purchase subsidies 4. Tax exemptions for EV purchase and use 5. Electricity subsidies 6. Reduced costs for charging 7. Free public parking lots 8. Access to special lanes (bus/HOV lanes) 9. License plate lottery policy 10. Personal carbon trading policy 11. Reduced air pollution 12. Reduced energy consumption 13. Pollution from producing batteries 14. Lack of battery recycling facilities 15. Limited driving range 16. Longer charging time 17. Fast initial acceleration 18. High speed 19. Less safety 20. Low reliability 21. Comfortable 22. Less maintenance 23. Low fuel economy 24. Ease of operation 25. Smoother to drive 26. Low engine noise 27. High purchase cost 28. Low fuel costs 29. Low maintenance costs 30. High battery replacement cost 31. Low quality of after-sales service 32. Unavailability of EV models at dealerships 33. Consumers' lack of market knowledge 34. Practical experience with driving EVs 35. EV-related knowledge 36. Daily use of an EV 37. More environmental benefits 38. Less fuel consumption 39. Necessary to society 40. Positive message to society 41. Affordability of EVs 42. Use of EVs in daily life

	43. Influenced by family, co-workers, and neighbors
	44. Peer pressure exerted by others
	45. Openness to new experience
	46. Negative emotions
	47. More efficient and self-disciplined
	48. More outgoing and energetic
	49. High motivation
	50. Better self-image
	51. Better social status
	52. Pride
	53. Feeling good about emission reduction contribution
	54. Socio-demographic variables

Step 3: Organize existing literature by sorting it into relevant MAP domains

To simplify and restructure the large number of determinants obtained from the literature reviews, we can sort them into their respective MAP domains (see Figure 5). Note that this overview combines some of the overlapping or similar determinants mentioned in Table 2, and discards some determinants that are indirect predictors of behaviour (e.g., personality traits, socio-demographic characteristics).

Costs & benefits	Moral motivations	Social motivations	Agency	Past Behaviour
Purchase costs	Environmental protection concerns	Subjective norms	Location/availability of charging stations	Previous experience w/ EV
Operational / maintenance costs / fuel costs	Environmental knowledge	Positive message to society	Perceived behavioural control	
Governmental incentives	Environmental benefits (GHG reduction, air pollution)	Influenced by family, co-workers, and neighbors	Lack of adequate staff at charging/service stations	
Aesthetics	Reduced energy consumption	Peer pressure exerted by others	Lack of battery recycling facilities	
Attitudes towards EV	Pollution from producing batteries	Better social status	Unavailability of EV models at dealerships	
Reduced noise	Necessary to society			
Time required to charge EV	Pride / better self-image / feeling good about emission reduction			
Speed / Power / Acceleration				
Range				
Fuel efficiency				
Less safety				
Low reliability				
Comfortable / smoother to drive				
Ease of operation				
Low quality of after-sales service				
Knowledge about EVs				

Figure 5. Overview of how the determinants of the adoption of electric vehicles fit into the

MAP-framework.

Based on this overview, we can now see that most of the determinants of the adoption of

electric vehicles are related to perceptions of the costs and benefits of electric vehicles.

Examples of perceived costs include buying and operating the vehicle, perceived

unreliability, and lower safety levels. Examples of benefits include less noise while driving,

comfort, and governmental incentives such as subsidies or priority parking. Perceived

agency seems also an important determinant, with especially the perceptions of the

available infrastructure to operate the electric vehicle (e.g., a sufficient number of charging

stations) being listed as a critical factor determining the adoption of the electric vehicle.

While moral and social motivations are also mentioned in both reviews, these factors are

discussed in less detail and seem to play a less prominent role[2].

Step 4: Select theory that covers the identified relevant MAP domains

The analysis in step 3 suggests that the drivers of electric vehicle adoption are primarily

cost and benefit motivations and perceived agency. Examining the MAP-framework

presented in Figure 4, we can determine that an appropriate theoretical framework to

represent the adoption of electric vehicles would therefore be Protection Motivation

Theory, because its constructs cover both the trade-off between costs and benefits of

driving an electric vehicle, as well as perceptions of agency by considering self- and

outcome efficacy. Indeed, the Protection Motivation Theory appeared to be successful in

explaining the adoption of electric vehicles (Bockarjova & Steg, 2014; Langbroek et al.,

2017). An alternative option could be the Theory of Planned Behaviour, which covers both

perceived costs and benefits and perceived agency (albeit in less detail than Protection

Motivation Theory), but which also includes social motivations as a possible additional

factor. Importantly, we recommend researchers do not attempt to include each individual

variable mentioned in the literature in their model, but rather rely on more overarching

theoretical constructs to reflect these considerations. For example, the higher purchasing

costs, smaller driving range, longer charging time, and lower reliability can all be subsumed

under 'perceived costs' of switching to an electric vehicle.

---

[2] It may also be the case that social and moral motivations do play an important role, but they have been understudied in the domain in question, and are therefore not represented accurately in literature reviews. Ensuring that environmental behaviour is studied from different theoretical perspectives is therefore an important imperative for environmental psychologists and other social scientists.

Overcoming the barrier of ambiguity

The MAP-framework addresses the problem of navigating the extensive environmental psychology literature when modelling the drivers of sustainable lifestyle change. However, this addresses only part of the challenge of modelling lifestyle change. Indeed, the second barrier that hinders the modelling of the drivers of environmental behaviour, ambiguity, remains: many theories in environmental psychology are yet not precise enough to unambiguously translate them into a mathematical model (e.g., Schlüter et al., 2017). When a model is developed based on a specific theory, there are typically many elements that need to be specified which are however often not considered in the original formulation of the theory, nor explored in the literature more broadly. As a result, researchers need to make many assumptions when they want to render psychological theories in a model (see for example Beckage et al., 2018). Indeed, modelling teams working with the same theory have come up with greatly varying models (Muelder & Filatova, 2018). This can be problematic, as different implementations of the same theory can yield different modelling results and conclusions, while it is often not clear which modelling approach should be considered best or most accurate (Muelder & Filatova, 2018). Reducing ambiguity by making theories more precise is therefore an important goal in order to improve and systematize the uptake of behavioural theories in modelling environmental behaviour. Below, we first identify three areas relating to the formulation and application of behavioural theories in environmental psychology that can contribute to ambiguity. We then offer a set of recommendations on how theorizing and the use of behavioural theories in environmental psychology can become more precise and standardized in order to reduce ambiguity and promote their systematic uptake in modelling the drivers of environmental behaviour.

1. *The definition and use of constructs*

498 The first area where ambiguity of theories can arise is the definition and application of key

499 constructs within theories. Constructs (also referred to as concepts, determinants, or variables)

500 refer to the individual components of a theory that jointly explain the dependent variable, in

501 this case environmental behaviour (see also Table 1 and Supplemental Material, listing the

502 key constructs included in the theories that form the MAP-framework). Currently, ambiguity

503 can arise because there are inconsistencies in how constructs are called, defined and measured

504 in the environmental psychology literature, and it is not always clear which exact set of

505 constructs are associated with a particular theory.

506 First, there can be inconsistencies in how the constructs that make up a theory are defined

507 and measured. For example, there is much discussion about how the concept of self-efficacy

508 (or *perceived behavioural control)* in the Theory of Planned Behaviour should be understood,

509 stemming partly from an unclear conceptualization within the original theory (e.g., Ajzen,

510 2006; Kraft et al., 2005). Similarly, the construct of risk perception within Protection

511 Motivation Theory is assessed in many different ways across studies: some researchers focus

512 on measuring its sub-components of perceived vulnerability and severity, while others assess

513 risk perception as a more overarching construct, often collapsing these two dimensions (Kothe

514 et al., 2020; van Valkengoed & Steg, 2019). Researchers also often do not explicitly provide

515 clear definitions of the constructs that they are studying (Bringmann et al., 2022; Flake &

516 Fried, 2020). This can inadvertently obscure differences between studies, as readers may

517 (incorrectly) assume that studies that mention the same constructs are also understanding and

518 measuring these constructs in the same way (also known as the "jingle" fallacy, see Flake &

519 Fried, 2020; Lilienfeld & Strother, 2020). Similarly, we have already shown in this article that

520 the same (or very similar) constructs may appear under different labels in different theories

521 (also known as the "jangle" fallacy, see Flake & Fried, 2020; Lilienfeld & Strother, 2020).

522 For example, the construct of outcome efficacy is also referred to as *outcome expectancy,*

523 *response efficacy,* and *ascription of responsibility* across the literature. The use of different

524 labels for the same constructs makes it more difficult to find relevant articles and to accurately

525 synthesize the literature.

526   Second, it is not always clear which set of constructs make up a theory. Many theories

527 represented in the MAP-framework have been proposed 20, 30, or even 40 years ago, and are

528 also used in different fields of application (e.g., understanding health behaviour, see Ogden,

529 2019). These theories have been tested frequently and by different researchers, over time

530 yielding insights on which parts of the theory are supported and where the theory can be

531 improved. Suggestions to remove or add constructs have been proposed, either by the original

532 authors of the theory, or by other researchers. For example, the first iteration of Protection

533 Motivation Theory did not include self-efficacy (Rogers, 1975) which was only added during

534 a later revision of the model (Rogers, 1983). Over time, different common practices within a

535 field may develop on how theories are tested. For example, the Theory of Planned Behaviour

536 proposes that attitudes, self-efficacy, and injunctive norms are predicted by behavioural

537 beliefs, control beliefs, and normative beliefs, respectively (Ajzen, 1991). Yet, these sets of

538 beliefs are rarely measured in practice, with most researchers testing only attitudes, self-

539 efficacy, and injunctive norms (e.g., Yuriev et al., 2020). Similarly, some components of

540 Protection Motivation Theory proposed by the original author, such as response costs (i.e., the

541 perceived costs associated with engaging in a behaviour), are only rarely included in tests or

542 discussions of the model (Kothe et al., 2020; Milne et al., 2000). When common practices

543 deviate from the original formulation of the theory, it may be unclear for researchers which

544 components of the theory should or should not be included, and how to determine why (not).

545 In sum, theories in psychology can be ambiguous because specific constructs are interpreted

546 and tested in different ways, and because it can be unclear which combination of constructs

547 represent a theory.

548   2. *Specifying relationships between constructs*

549   A second area where theories can be ambiguous is in the description of the relationships

550   between constructs. First, relationships between two constructs in theories are often described

551   in terms of the direction and causality of the relationship, meaning that the relationship is

552   described as either positive or negative (e.g., higher self-efficacy is positively associated with

553   stronger intentions to act pro-environmentally; Edwards & Berry, 2010). When a

554   mathematical model is specified on the basis of a theory, it is however necessary to specify

555   the shape of the relationship between two constructs, too (i.e., whether the relationship is

556   linear, sigmoidal, curvilinear, or another shape, e.g., Schlüter et al., 2017). This information is

557   often not provided within the original propositions of theories, and in studying environmental

558   behaviour, researchers rarely make and test hypotheses about the shape of relationships

559   between constructs. When testing theories, researchers often by default test linear

560   relationships, which is the underlying assumption in many standard statistical tests (Edwards

561   & Berry, 2010). There is thus very little information available about the shape of the

562   relationships between constructs in a model. Importantly, specifying different relationship

563   shapes (i.e., linear, curvilinear or sigmoidal) does affect the results of models representing the

564   drivers of environmental behaviour (Beckage et al., 2018), and this aspect of constructing a

565   model should therefore not be ignored or overlooked.

566   Second, descriptions of theories are often unclear on how more complex relationships

567   between three or more constructs should be interpreted or tested. For example, within the

568   Theory of Planned Behaviours it unclear whether self-efficacy should be considered a

569   moderator of the relationship between intentions and behaviour, a direct predictor of

570   behaviour, or both (e.g., Hagger et al., 2022). In addition, it is not clearly specified what

571   relationships and/or interactions between attitudes, self-efficacy, and perceived subjective

572   norms are expected (Hagger et al., 2022). As another example, Protection Motivation Theory

573 proposes that risk perception, self-efficacy, and outcome efficacy interact as follows: *if*

574 *[outcome efficacy] and/or self-efficacy are high, then increases in [risk perception] will*

575 *produce a positive main effect [on behaviour]. On the other hand, if outcome efficacy and/or*

576 *self-efficacy are low, then increases in [risk perception] will either have no effect or a*

577 *boomerang effect, actually reducing intentions* (Rogers, 1983, p. 156)[3]. Yet, this description

578 does not clearly state what relationship is expected if self-efficacy is high and outcome

579 efficacy is low, or vice versa, nor does it specify when no effect or a boomerang effect may be

580 expected (Weinstein, 1993). What the exact configuration of a theoretical model looks like is

581 therefore not always self-evident.

582   Third, many theories do not specify how relationships between constructs may develop

583 over time (e.g., Vancouver et al., 2018). Psychological theories are often focused on

584 describing when a particular behaviour is more or less likely to occur, and the relationships

585 between constructs and the dependent variable often represent a snap shot at a particular point

586 in time. Far fewer theories explicitly consider how the relationships between constructs and

587 the dependent variable may develop over time, for example by considering feedback loops

588 after a behaviour occurs (Davis et al., 2015; Roe, 2008). The aim of IAMs is typically to

589 examine how outcomes develop over time, and specifying potential feedback loops between

590 determinants and behaviour in the model is therefore essential (van Vuuren et al., 2018).

591 Hence, ambiguity can currently arise regarding how changes over time should be represented.

592   Some examples of potential feedback loops were already discussed above within the

593 MAP-framework. For example, engaging in pro-environmental behaviour could strengthen

594 people's environmental self-identity, which in turn motivates people to engage in more pro-

595 environmental behaviour (Van der Werff et al., 2013). Within some of the other discussed

596 theories, it is also possible that feedback loops occur, even though they are not explicitly part

[3] Words between brackets indicate changes made to the original quote by the authors to keep the labelling of constructs consistent in this paper.

597 of the original model. For example, within the framework of the Theory of Planned

598 Behaviour, it has been proposed that if people have acted pro-environmentally and had a good

599 or bad experience with it, this could influence their attitudes towards the behaviour, which in

600 turn affects the likelihood that they will engage in the behaviour again (Albarracín & Wyer,

601 2000; Fishbein, 2010). Similarly, by engaging in pro-environmental behaviour people may

602 realise the behaviour was more or less difficult to perform than anticipated, which could

603 increase or decrease their sense of self-efficacy, respectively (Fishbein, 2010). More

604 systematically theorizing about and testing such temporal dynamics is thus a critical step for

605 theory development.

606 *3. Strength of relationships and boundary conditions of theories*

607 A final reason where theorizing may be ambiguous is because the strength of relationships

608 between model variables is rarely predicted or specified. As previously mentioned,

609 relationships between constructs within theories are mostly described in terms of their

610 direction only (i.e., which variable predicts which, and is it a positive or negative

611 relationship). Yet, to specify a mathematical model, it is also necessary to indicate the

612 strength of the relationship between constructs. One way to circumvent this problem could be

613 to rely on meta-analyses to gain information on the average strength of relationships between

614 constructs across studies. However, many meta-analyses report a high level of heterogeneity

615 between studies (Linden & Honekopp, 2021 see for example van Valkengoed & Steg (2019)),

616 which can often only be explained to a limited extent because there is limited theorizing and

617 empirical evidence on which moderators may account for this heterogeneity (Bryan et al.,

618 2021; Linden & Honekopp, 2021). Hence, it is typically unclear how strong of a relationship

619 between constructs can be expected, and under which conditions we can expect that the

620 relationship is stronger or weaker. The inability to account for this heterogeneity may be

621 partially due to the fact that many theories do not clearly specify the boundary conditions

622 under which the theory is most applicable (Bryan et al., 2021). The lack of theorizing on the

623 strength of the relationships under different conditions, and the often observed but

624 unaccounted heterogeneity between studies thus forms a final source of ambiguity.

625 *Recommendations to reduce ambiguity in theories and their application*

626   To reduce these sources of ambiguity and increase the precision of theories in

627 environmental psychology used to explain environmental behaviour, we offer three

628 recommendations to social and behavioural scientists conducting theoretical and empirical

629 work on the driver of environmental behaviour. First, we recommend that researchers testing

630 theories should be much more transparent and explicit in describing their theory. At

631 minimum, researchers need to clearly describe 1) which constructs they consider part of the

632 theory and justify why they focus on that specific set of constructs, 2) offer clear and precise

633 labels, definitions and operationalisations for the constructs they are examining (see also

634 Flake & Fried, 2020), and 3) make clear which relationships they expect between constructs,

635 including possible moderation and mediation effects, specifying the strength of these

636 relationships and considering possible feedback loops between determinants and behaviour.

637   Second, we recommend that researchers in environmental psychology strive to work

638 towards a consensus on how theories are understood and tested, which is regularly updated to

639 accurately reflect the current state of the art. Review articles can contribute to this by tracking

640 developments in theories over time, and by mapping differences in the understanding and

641 application of a theory. Expert consensus methods, such as expert group meetings and

642 workshops, can subsequently be used to address and resolve potential discrepancies in how

643 researchers understand and test theories, and to develop agreed-upon configurations of

644 theories and definitions of key constructs (see for example Hagger et al., 2016; Michie et al.,

645 2005). Importantly, to reduce the variability between studies in terms of the measurement of

646 constructs, it is important that the research community develops and agrees upon the use of

647 standardized and validated measures to assess constructs, as well as using the same label for

648 each construct consistently (see Flake & Fried, 2020). The current state of art should ideally

649 also be easily accessible and updatable, for example via regularly updated review articles,

650 community wikis, textbooks or encyclopaedia projects (Steg & de Groot, 2019).

651   Third, there is a need for novel theorizing to address some of the sources of ambiguity.

652 Specifically, theorizing is necessary on the functional form of relationships between

653 constructs within a theory, the strength of those relationships, and how relationships develop

654 over time. It is also necessary that heterogeneity between studies is better accounted for,

655 which requires more exact specification of the boundary conditions of theories. Novel

656 theorizing also invites novel empirical work to test such propositions.

657

658 **Conclusion**

659   Lifestyle change represents a promising demand-side solution that can deliver

660 substantial reductions in CO_2 emissions, lowering the need for risky carbon capture and

661 storage technologies. and increasing the likelihood that we can limit climate change to below

662 $2°C$. To understand and maximize the potential of lifestyle changes, it is important to

663 accurately model the drivers of these behavioural changes in IAMs. We see great potential for

664 environmental psychology to contribute key insights to modelling the drivers of lifestyle

665 changes, but there are key barriers that need to be addressed before this can happen in a

666 systematic and valid way. Specifically, there needs to be better guidance for researchers on

667 how to navigate the expansive environmental psychology literature, and theories need to

668 become more precise in order to reduce ambiguity and to ease the process of rendering

669 theories mathematically. We hope the MAP-framework we introduced in this article, as well

670 as our recommendations for making theories more precise, can contribute to reducing these

671 barriers and expedite the systematic uptake of environmental psychology literature in the

672   modelling of the drivers of lifestyle change. Yet, the recommendations in this article will

673   only be useful if they are taken up by environmental psychologists and integrated assessment

674   modellers alike. The modelling of the drivers of environmental behaviour can only succeed if

675   there are close collaborations between integrated assessment modellers and environmental

676   psychologists. So far, environmental psychologists have hardly been involved in the

677   discussion on the modelling of lifestyle changes, and we therefore urge them to more actively

678   participate, for example by more explicitly considering implications for modelling in their

679   theorizing and studies, and by taking up the research recommendations provided in this article

680   to make theorizing more specific. We ask integrated assessment modellers to continue

681   inviting environmental psychologists and other social and behavioural scientists to contribute

682   to their efforts, for example by asking for recommendations or feedback on which theories are

683   most suitable to modelling particular behaviours of lifestyle changes, or on how particular

684   theories can best be represented. Such collaborations can represent win-win situations that

685   benefit both the behavioural realism of lifestyle models, improve the development and

686   refinement of psychological theories, and ultimately provide critical insights on how to utilize

687   the potential of lifestyle change to limit climate change to $2°C$.

688

689

690

Table 1

Overview of the original purpose and key constructs of the eight behavioural theories within the MAP-framework, and suggested application of the theory in modelling.

Theory	Original purpose	Key constructs	Suggested modelling application	Potential sources for parametrization of models
Theory of planned behaviour	Explaining planned behaviour (i.e., behaviour that people consciously plan to do)	- Attitudes - Injunctive norms - Self-efficacy - (Intentions)*	- Understanding the influence of perceived personal costs and benefits on pro-environmental behaviour - Modelling effects of policies or societal developments that change the perceived costs and benefits of behaviour (e.g., price policies)	Yuriev et al., (2020). Pro-environnmental behaviors through the lends of the theory of planned behaviour: A scoping review. *Resources, Conservation and Recycling*, 155, 104660.
Protection Motivation Theory	Explaining how people respond to threats	- Risk perception - Maladaptive response rewards - Response costs - Self-efficacy - Outcome efficacy	- Understanding people's responses to climate-related hazards - Modelling effects of policies or societal developments that increase perceived risks of climate change, or increase efficacy to respond	Kothe et al., (2019). Protection motivation theory and pro-environmental behaviour: a systematic mapping review. *Australian Journal of Psychology, 71*(4), 411-432

Norm Activation Model / Value-Belief Norm Theory	Explaining when people engage in moral behaviour, or behaviour that benefits others even if this involves some personal costs	- Biospheric, Altruistic, Egoistic, and Hedonic, values (VBN) - Problem awareness - Outcome efficacy - Personal norm	- Understanding when people 'self-sacrifice', or engage in moral behaviour that does not benefit themselves directly but benefits others or the environment - Modelling effects of policies or societal developments that strengthen people's biospheric or altruistic values (or weaken egoistic or hedonic values), or that increase problem awareness, outcome efficacy, or personal norms on pro-environmental behaviour.	No overview article summarizing studies on Norm Activation Model / VBN available yet
Environmental self-identity theory	Explaining how people's sense of identity as an environmental person can lead them to act pro-environmentally.	- Biospheric values - Past behaviour - Environmental self-identity -	- Understanding how environmental self-identity can develop based on biospheric values and past behaviour - Modelling effects of interventions or societal developments that strengthen environmental self-identity by strengthen biospheric values or reminding people of past pro-environmental behaviour.	Vesely et al. (2021) Climate change action as a project of identity: Eight meta-analyses. *Global Environmental Change*, 70, 102322.
Focus Theory of Normative Conduct	Explaining how social norms influence behaviour	- Descriptive norms - Injunctive norms	- Understanding how people's environmental behaviour depends on the perceived behaviour and expectations of other people - Modelling effects of interventions or societal developments that change (perceptions of) descriptive and injunctive norms.	Farrow et al. (2017). Social norms and pro-environmental behaviour: A review of the evidence. *Ecological economics,* 140, 1-13.
Social Identity Approach	Explaining how individual's beliefs and behaviours are influenced by group membership	- Perceived group goals and values - Collective efficacy - Group identification**	- Understanding how people's affiliation with certain groups (e.g., political affiliation) can affect pro-environmental behaviour via perceived group goals and values and collective efficacy - Modelling effects of interventions or societal developments that change group goals and values or	Fielding & Hornsey (2016). A Social Identity Analysis of Climate Change and Environmental Attitudes and Behaviors: Insights and Opportunities. *Frontiers in Psychology*, 7, 121.

			collective efficacy in order to promote pro-environmental behaviour.	
Habit Theory	Explain how behaviour and behaviour change is affected by people's habits	- Habit strength - Contextual cues **	- Understanding how habits affect changes in environmental behaviours - Modelling the effects of behaviour change interventions on behaviour change, taking into account habit strength.	No overview article summarizing studies on habit theory and environmental behaviour available yet

* intentions form part of the TPB framework, but are not mentioned as a separate motivation in the MAP-framework, as it is not a motivation in itself, but rather is reflective of the fact that the TPB framework by definition focusses on planned actions that are preceded by an intention.

* Group identification and contextual cues serve as moderating factors within their respecting theories, and are not direct predictors of behaviour (see Figure 1). They are therefore not discussed as motivating factors within the MAP-framework, but are listed here to give a representative overview of each theory.

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