

BEHAVIOURAL CHANGE ASSESSMENT IN 39 CITIES OF THE EU MISSION AIMING AT CLIMATE-NEUTRAL AND SMART CITIES

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ABSTRACT

Large-scale socio-technical transformations in cities require addressing behavioural change among citizens as a vital part of their climate transition pathways. Traditional, siloed, top-down methods, which focused mainly on reducing greenhouse gas (GHG) emissions through technological innovation, are increasingly seen as insufficient to address the complexities of transitioning to climate neutrality. In response, cities are adopting systemic approaches that integrate bottom-up strategies such as social innovation to reshape and strengthen climate action plans, fostering deep sustainability and enabling climate-neutral urban ecosystems that drive lasting and meaningful change. Within a systemic perspective, integrating behavioural insights (BI) strategically into policy design is essential for realistically achieving climate-neutral objectives. Although behavioural change at the individual level has been extensively examined across disciplines, transdisciplinary literature provides limited insights into its role in systemic urban transformations. Despite a growing consensus among policymakers, urban transition teams, and scholars on the necessity of integrating behavioural change into climate action research, little empirical evidence exists on how it can be operationalised in practice. To address this gap, this study examines how cities plan to monitor and evaluate the impacts of their climate actions on citizens' behaviour change. Focusing on the European Union's mission of achieving 100 climate-neutral and smart cities by 2030, this study examines the selection of non-GHG indicators by 39 cities involved in the NetZeroCities project. Using an adaptation of the Transtheoretical Model of Behaviour Change, cities' selections of indicators are categorised according to the stages of behavioural change they target. The findings provide evidence of cities' perceived importance of behavioural change actions and assessment within systemic climate transitions and highlight the stages prioritised by European cities. The study also advances transdisciplinary discourse on systemic climate transitions, presenting cities' choices in terms of behavioural change assessment by emission domain, and by geographic region, thus offering insights on the behavioural change as a lever of climate interventions for policymakers and public administrations to support comprehensive urban planning strategies that effectively embed human behaviour.

KEYWORDS

Monitoring, Behavioural Change, Systemic Transformation, Climate Neutrality, Cities, Evaluation Framework, Transtheoretical Model of Behaviour Change (TTM)

1. INTRODUCTION

Cities worldwide are increasingly adopting systemic approaches to confront the urgent challenge of climate change and align with the 2030 targets of the Paris Agreement, which seeks to limit global warming to 1.5°C (IPCC, 2022; United Nations, 2023). Traditional climate strategies, primarily centred on technological and infrastructural solutions alone, have so far demonstrated limited effectiveness in generating substantive progress in achieving climate neutrality (Repo & Matschoss, 2019). Newell et al. (2021) argue that meeting climate goals requires profound shifts in lifestyles, policy frameworks, service provision, and technological innovation. Household-related emissions, which constitute between 50% and 75% of global greenhouse gas emissions (Hertwich & Peters, 2009), underscore the critical role of enabling pro-environmental behavioural changes and lifestyle choices in mitigating climate impacts (Hertwich and Peters, 2009; Hirano et al., 2016; Akenji et al., 2019; Ivanova et al., 2020). Furthermore, there is a growing consensus among international organisations, municipalities, and scholars to embed bottom-up strategies within climate action portfolios of cities that enable behavioural transformations of citizens (Bernauer, 2013; Sabel and Victor, 2017). However, the extent to which such interventions can be implemented and assessed with sufficient speed, efficiency and accuracy to achieve significant global progress in climate neutrality remains uncertain.

A critical lesson from climate action shortcomings identified in the literature is the need to distinguish between shallow and deep scaling of behavioural interventions, as outlined by Newell et al. (2021). Shallow scaling fails to account for the contextual determinants of behaviour, relying on surface-level mechanisms such as political incentives, market forces, or nudges (Schwartz, 1977; Cialdini et al., 1990). In contrast, deep scaling aims to bring about societal transformation by embedding sustainable norms and values within cultural and institutional practices. Deep scaling of behavioural change within the socio-cultural fabric of cities requires a non-linear, multidimensional approach that accounts for the complexities of social and psychological dynamics.

Additionally, individual-level barriers, including financial constraints, inadequate infrastructure, and ingrained social norms, limit the capacity for behavioural change (Cialdini et al., 1990; Gifford & Nilsson, 2014). Cognitive biases and psychological factors further complicate this process, reinforcing the need for robust theoretical frameworks to guide effective, systemic interventions (Kahneman, 2012; Haselton et al., 2015).

Human behaviour and behavioural change have been widely studied at the individual level, drawing on theoretical frameworks originating in cognitive psychology and related disciplines. In Social Science Theory for Environmental Sustainability, Stern (2018) invokes Richard Thaler's distinction between real humans and the hypothetical "Econs" of traditional economic models. Unlike Econs, assumed to act with perfect rationality in pursuit of self-interest, humans rarely have complete knowledge of a problem and often make choices shaped by factors beyond rational optimisation. This recognition has long underpinned psychological theories of heuristics, which explain decision-making as constrained by cognitive limits (Simon, 1955; Rachlin, 2003). Tversky and Kahneman (1974) describe heuristics as simplified rules of judgment under uncertainty, while Kahneman (2012) elaborates this further through his dual-process model of fast, intuitive (System 1) and slow, deliberative (System 2) thinking.

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Beyond heuristics, psychology has produced several behavioural change models that have been widely applied across disciplines, including sustainability studies. Social norms, shared standards of appropriate behaviour, are central to climate-related behavioural change (Stern, 2018). Drawing on Cialdini et al. (1990), these may be descriptive (based on perceptions of what most people do) or injunctive (based on perceptions of what others approve or expect). Together, they illustrate how behaviour is shaped by conformity and social pressure. Such insights underpin broader theoretical approaches, including Schwartz's (1977) Norm Activation Model and Ajzen's (1991) Theory of Planned Behaviour. This remains one of the most widely used frameworks, positing that behaviour is shaped by attitudes toward outcomes, subjective norms, and perceived behavioural control. Its strength lies in linking individual agency, social influence, and self-efficacy to behavioural intentions, making it particularly relevant to sustainability interventions (Savari et al., 2023; Stern, 2018).

Prochaska et al.'s (1994) Transtheoretical Model of Change further contributes to this literature, conceptualising behavioural change as a staged process, including the possibility of relapse. Initially developed in psychotherapy, it has since been applied across diverse domains such as health, transport, and consumer behaviour, and provides useful insights for sustainability transitions.

Despite the extensive use of such models, their application to systemic transformations, particularly in the context of climate neutrality, remains limited. While it is difficult to assess behavioural change in systemic interventions at the urban scale, the EU Missions on climate provide a unique field experiment in which to test behavioural change theories in systemic change urban action planning across countries.

Despite increasing recognition of the importance of behavioural change within systemic transformations, the integration of behavioural insights (BI) into climate policy remains a crucial but still underexplored field (European Commission, Joint Research Centre, 2025). There is a growing consensus among policymakers, urban transition teams, and scholars for the early incorporation of BI into the policy cycle to enhance the effectiveness of interventions aiming at systemic change, challenging the traditional focus of climate urban planning on interventions aimed at changing individual behaviour within existing systems, and proposing transforming the systems themselves (Rutter et al., 2017).

Cities in Europe are in the early stages of adopting a systemic approach to climate neutrality as part of their commitment to the EU Mission, "100 Climate-Neutral and Smart Cities by 2030" (European Commission, 2021). This study examines the role of behavioural change within systemic transformations for climate neutrality, drawing on early evidence from the EU-funded NetZeroCities (NZC) project (<https://netzerocities.eu/>). Specifically, it explores how cities are planning to implement and monitor behavioural change interventions. The NetZeroCities project supports EU cities in achieving climate neutrality by 2030 by offering tools, expertise, learning opportunities and a shared knowledge platform. Beyond reducing GHG emissions, it aims to drive systemic change through social innovation and citizen participation for a just transition.

This study addresses the research question: What is the emerging evidence of European cities' plans to monitor and evaluate the impact of their climate actions on citizens' behavioural change?

Cities participating in the project have submitted their pilot projects, which support the goal of reaching climate neutrality, describing a set of actions and related indicators to track progress. By analysing the pilot project plans submitted by 39 European cities, specifically their selection of indicators based on the NetZeroCities standardised indicator set (available on the project

website) and customised indicators proposed by the cities, this study identifies emerging trends in how municipalities are addressing behavioural change. Specifically, it reveals: (1) patterns in indicator selection related to citizen behavioural change, and (2) the behavioural change stages which cities aim to assess, based on an adapted Transtheoretical Model (Prochaska et al., 1994). Preliminary insights from the analysis of the indicator selection of the cities were published in the proceedings of the Connected Smart Cities Conference, Lisbon, 2025 (Mondal et al., 2025). This paper builds on initial findings and presents a comprehensive analysis of the behavioural change indicators selected by the cities in relation to 6 emission domains and 6 systemic levers used by the cities to categorise their climate interventions. The novel insights derived from this study not only contribute to the broader academic discourse on behavioural change in systemic transformations but also provide timely and crucial support for holistic, evidence-based climate policymaking that integrates behavioural insights.

2. APPLYING THE TRANSTHEORETICAL MODEL TO STUDY BEHAVIOURAL CHANGE

Prochaska et al.'s Transtheoretical Model of Change (1994), originally developed to assess an individual's readiness to adopt healthier behaviour within the context of psychotherapy, proposes five distinct stages of behavioural change: precontemplation, contemplation, preparation, action, and maintenance. Additionally, the model incorporates a potential sixth stage signifying "Termination", which represents the failure to maintain the implemented behavioural change, as well as the concept of "Relapse", denoting a regression from the "Action" or "Maintenance" stage to an earlier phase. TTM has been widely adopted across disciplines such as consumer studies (Mitrega et al., 2022), climate education (Inman and Jeffrey, 2006) and transportation (Rizki et al., 2024) owing to its generalisability across domains. In this study, the model is used to categorise behavioural change indicators within the context of climate neutrality to assess which stage of behavioural change they correspond to (Figure 1).

2.1 Stages of Change

The Transtheoretical Model (TTM; Prochaska et al. 1994) outlines six stages of behavioural change:

- 1. Precontemplation:** At this stage, the individual is unaware of the negative consequences of their current behaviour and exhibits no intention of initiating behavioural change.
- 2. Contemplation:** Often referred to as the "*getting ready*" stage, this phase is characterised by the individual's recognition of the need for behavioural change due to the adverse consequences of their current actions. However, despite acknowledging the necessity of change, the individual remains undecided, weighing the potential benefits and drawbacks without committing to action.
- 3. Preparation:** At this stage, the individual demonstrates a clear intent to modify their behaviour in the near future. This is reflected in proactive planning and the initiation of preparatory steps essential for successful change.

4. Action: The individual actively implements the intended behavioural modifications, thereby altering their previous behavioural patterns.

5. Maintenance: This stage signifies the sustained continuation of the newly adopted behaviour, with conscious efforts to prevent relapse or termination. Individuals in this phase work to reinforce and integrate the behavioural change into their daily lives, minimising the likelihood of regression to previous habits of the behavioural change.

6. Termination: This is the stage where the individual fails to maintain the implemented behavioural change and thus the progress “relapses” to prior stages.

2.2 Adaptation of the Model

In this study the data provided by cities do not allow for the measurement of precontemplation or termination, thus the model (Prochaska, et al. 1994) has been adapted by focusing on three consolidated categories (Figure 1) for which the data submitted by cities are available, partly aligning with the I-change model (Vries et al., 2005): (a) awareness, (b) intention and (3) action.

a. Awareness: This stage encompasses interventions corresponding to the second stage of the TTM, Contemplation. It aligns with soft climate adaptation strategies (Sovacool, 2011), which primarily involve initiatives that nudge or attempt to raise awareness among citizens. Such interventions aim to inform and encourage behavioural change without necessarily prompting immediate action. For instance, increased nudging towards sustainable commuting within organisations exemplifies this stage. The intervention seeks to nudge citizens towards Pro-Environmental Behaviours or PEBs (Gifford & Nilsson, 2014), yet it does not track whether individuals are actively engaging in or practising the behaviour.

b. Intention: This category includes interventions that primarily address the Preparation stage of the TTM. Interventions at this level are more structured than those in the Awareness stage, as they focus on increasing the active involvement of citizens in adopting PEBs. However, such interventions remain voluntary and, while they may motivate, inspire, and prepare citizens for PEB, they do not ensure sustained systemic adoption. An example of this is the Citizens’ Capacitation Programme aimed at carbon neutrality. Success is measured by the number of citizens actively participating in the programme. Although the intervention fosters engagement towards climate neutrality, it does not enforce sustained participation.

c. Action: This final stage encompasses the Action to Maintenance phases of the TTM and includes interventions designed to ensure a higher degree of citizen participation, either through hard and soft policy measures or normative influence. For example, an intervention that encourages an increased number of employees to shift to sustainable commuting would be classified here. This stage typically involves enforceable measures that seek to ensure consistent and sustained behavioural change within a specific citizen group.

The above 3 categories were used not only to mark indicators of behavioural change but also to specify at what behavioural stage the interventions are likely to make an impact based on an adaptation of TTM.

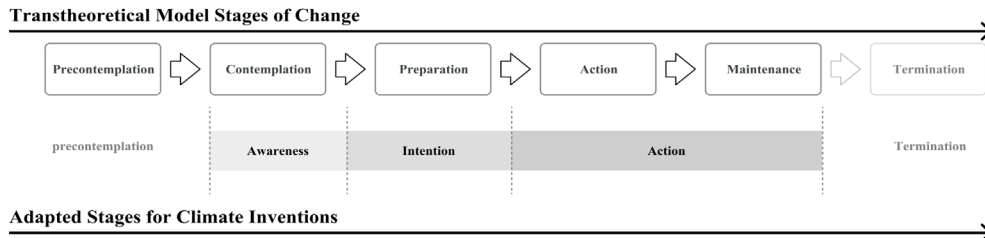


Figure 1. Transtheoretical Model Stages of Change adapted to study climate interventions towards systemic behavioural change
(Source: Adapted from the TTM stages of change by Prochaska et al., 1994)

3. EMPIRICAL DATA SOURCES

The 39 cities of the NZC project included in this study are the first cohort of Pilot cities, which submitted their initial proposal refinement documents to strategise their climate actions and select monitoring, evaluation and learning indicators (Chaudhary et al., 2022).

The pilot projects (described at: <https://netzerocities.eu/pilot-cities-cohort-1-2022/>) in this study include:

Net Zero Investment Co-Innovation Lab (Bristol, UK), *Budapest CARES* (Budapest, Hungary), *Blueprint for Net-Zero Apartment-block Neighbourhoods* (Cluj-Napoca, Romania), *Green and Carbon Neutral Building Transition Guide – Istanbul Model* (Istanbul, Türkiye), *NEUTRON* (Kozani, Greece), *SCALE UP* (Uppsala, Sweden), *Systemic change towards sustainable commuting in Lahti* (Lahti, Finland), *Let'sGOv* (Bologna; Bergamo; Florence; Milan; Padova; Parma; Prato; Rome; Turin, Italy), *Leuven's Pilot Project* (Leuven, Belgium), *The Initiation of Sustainable Energy Community for the City of Liberec* (Liberec, Czech Republic), *Limassol City Cooling Challenge* (Limassol, Cyprus), *Net Zero Malmö Pilot* (Malmö, Sweden), *Together Toward Climate Neutrality* (Nantes, France), *NEEST* (Krakow; Łódź; Rzeszów; Warsaw; Wrocław, Poland), *Creating NetZero Vision for Rivne* (Rivne, Ukraine), *URBANEW* (Barcelona; Madrid; Seville; Valencia; Valladolid; Vitoria-Gasteiz; Zaragoza, Spain), *1.5-Degree City* (Turku, Finland), *The North Star* (Umeå, Sweden), and *UP-SCALE* (Kranj; Ljubljana; Velenje, Slovenia).

Municipalities were provided with templates to present their planned pilot activities. This required cities to describe not only direct impacts of implementing actions to reduce GHG emissions and their co-benefits (i.e., air quality) but also long-term non-GHG impacts of their climate interventions, such as social inclusion. This study focuses specifically on analysing both standardised indicators selected from the indicator framework provided to cities by the project and customised indicators self-selected by cities to measure the impact of their planned long-term non-GHG interventions and Co-benefit (i.e., indirect benefits) of climate actions.

4. METHODOLOGY

The analysis followed a three-step process: (1) mapping and categorisation of the indicators related to behavioural change from the pilot projects submitted by all 39 cities based on a compilation of all the indicators submitted (Mondal et al., 2024); (2) coding of the dataset to assess the indicator of behavioural change (Carter et al., 2014) based on the above described model; and (3) analysis by emission domain and by country to extract key insights. Inputs were compiled in a spreadsheet, with each intervention reviewed and its indicator selections recorded. Indicators related to behavioural change were identified and independently coded by two researchers into the categories of Awareness, Intention, and Action. Discrepancies in coding were resolved through discussion. The final coded dataset was then analysed to identify recurring trends in indicator selection. The coded list of 38 behavioural change indicators as per the cities' selection is provided in Table 1. These indicators have been analysed in terms of stages of behavioural change (i.e., Awareness, Intention and Action) and have been further evaluated in relation to the emission domains and systemic levers they correspond to. The following section highlights the key findings of this analysis that serve as early evidence of the emerging plans of cities for monitoring and evaluating behavioural change within systemic climate transitions.

5. ANALYSIS AND FINDINGS

A total of 198 indicators were proposed by the 39 cities (Mondal et al. 2024), out of which 38 unique behavioural change indicators were identified in this study that relate to one of the 3 stages of the proposed model: Awareness, Intention and Action. These indicators align with the theory of change proposed by each city to plan their impact pathways to reach climate neutrality by 2030, following a portfolio-driven approach.

Among the indicators selected by the cities, only 2 unique standardised indicators were found to address behavioural change, in contrast to 36 unique customised indicators developed by the cities to reflect their specific contexts. This contrast suggests that cities recognise the relevance of behavioural change assessment in climate action urban planning. This highlights the need for researchers to identify and provide cities with useful and theoretically sound indicators for monitoring, assessment and learning from climate actions.

Among all the indicators selected by cities, 35% (18 out of 52) of customised (i.e., self-selected) long-term non-GHG interventions and 32% (18 out of 56) of customised indirect benefits of climate interventions (also referred to as "customised co-benefits" within the NZC project) were linked to direct or indirect systemic behavioural changes. In contrast, only 4.4% (4 out of 90) of standardised co-benefit interventions addressed behavioural change. A plausible explanation for the disproportionate difference between standardised and customised indicators is the absence of a defined "behavioural change" indicator within the list of standardised indicators provided to cities, while cities express the need to monitor the behavioural change of various actors. This observation highlights an emerging trend in climate interventions being undertaken by cities, which increasingly aim to address behavioural change at a systemic level. It also underscores the potential for the NZC project standardised indicator framework to integrate behavioural change indicators, drawing on the trend of customised indicator selections made by cities, and aligning them with the stages of behavioural change as outlined by the Transtheoretical Model of Change.

Table 1. Coding of Cities' Indicator selections into stages of Behavioural Change (Awareness, Intention or Action)

Indicator Selections by Cities	Custom metric/unit of measurement	TTM Stages
Customised according to city/project		
Co-Design Events	Number of Co-design Events	<i>Awareness</i>
Share of citizens with eco-friendly behaviours [Faster reduction of behavioural barriers]	%	<i>Awareness</i>
Share of citizens with eco-friendly behaviours [Collective mindset directed towards achieving climate neutrality]	%	<i>Intention</i>
Resident engagement in energy and climate conscious actions	Surveys (Likert Scale 1-5: 4)	<i>Action</i>
Degree of satisfaction and acceptance of residents affected by the actions in the project	Surveys (Likert Scale 1-5: 4)	
Participation percentage - No. of stakeholders	% or Number of stakeholders	<i>Awareness</i>
No. of users of public transport system	Total Number of users	<i>Action</i>
No. of interventions in case organisation during the project	Number of interventions	<i>Awareness</i>
Incentives/Work benefits offered by the employers (value/employee)	euros/employee	<i>Intention</i>
Share of employees in participating in interventions	% of all employees in case organisations	<i>Action</i>
Increase in grassroots initiatives	Number of new grassroots initiatives in energy	<i>Awareness</i>
Level of sense of agency among stakeholders and residents	Likert scale; 5 scales to be determined in survey	<i>Action</i>
Social spectrograph [Actively involve shareholders and citizens through participatory solution]	NA	<i>Intention</i>
Social spectrograph [Forming Social Alliances through listening and communication]	NA	<i>Intention</i>
Number of neighbourhoods with partnerships	NA	<i>Awareness</i>
Improved citizen participation per city / district (estimations)	Number of citizens engaged through the Pilot activities	<i>Action</i>
Behaviour changes data collection, using both objective (e.g., electronic traffic counting) and subjective (e.g., survey questionnaires, interviews) measures.	NA	<i>Awareness</i>
Increase in Public Awareness	NA	<i>Awareness</i>
Behavioural changes among tenants could lead to more sustainable lifestyles	NA	<i>Action</i>

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Standardised		
Improved citizen participation (Selected 3 times)	Number of citizens engaged through the Pilot activities	<i>Intention</i>
Social Cohesion	NA	<i>Awareness</i>
Long-term non-GHG Impacts (Customised according to city/project)		
Participants to project activities	Number	<i>Awareness</i>
Number of Projects	Number of citizens engaged through the Pilot activities	<i>Awareness</i>
	Number of newsletters and/or press releases produced.	
Number of participants	Number of public officers trained through the Pilot activities total number of counselled activities	<i>Intention</i>
% of citizens participating in energy-related initiatives	%	<i>Action</i>
Increase of stable agreements & collaborations with relevant energy stakeholders in cities	Number of protocols, pathways, collaborations, memoranda of understanding involving relevant stakeholders	<i>Awareness</i>
Online Platform Visitors	Total Number of Visitors	<i>Awareness</i>
Social spectrograph	Socially weighted average distance from 'aware'	<i>Action</i>
Accelerated, socially peaceful change towards NZC	Socially weighted average distance from 'aware'	<i>Intention</i>
Acceptance of solutions		
Climate impact per capita of consumption	t CO2 equivalents / year	<i>Action</i>
Successful operational changes made	Number as identified	<i>Intention</i>
Number of community engagement activities	Number as identified	<i>Awareness</i>
Number of REC triggered by the project	Number of REC triggered by the project	<i>Intention</i>
Feedback of the organised events, trainings & webinars for the Climate team	Number of organised events, trainings and webinars Number of participants	<i>Intention</i>
Observable changes in the behaviour of citizens towards climate neutrality	Indicators different per type of emission, measured using existing general tools	<i>Action</i>
Awareness & ability to work across silos, formalised changes in policy, governance, organisational structure, budgets, etc. (Selected 2 times for different pilot actions)	Self-assessment Review of changes in yearly reports, number of climate instigated organisational changes, implemented recommendations from project	<i>Intention</i>
Number of citizens participating to the capacitation programme activities	Number of participants registered at the trainings, customised events and on the monitoring platform	<i>Intention</i>

Based on the initial analysis, out of all the behavioural change-related non-GHG indicators proposed by the cities to measure the long-term impact of their climate interventions, 27.78% aligned with Awareness, 50% with Intention, and 22.23% with Action (Figure 2).

However, further analysis revealed that when cities listed indicators to measure the co-benefits of their planned climate actions, 44.45% related to Awareness, 22.23% were linked with Intention and 33.34% of them aligned with Action (Figure 3). In other words, the Cities' proposed non-GHG indicators, such as "(%) Share of citizens with eco-friendly behaviours" and "Improved citizen participation", are primarily observed to be associated with the early and middle stages of behavioural change (Awareness and Intention).

Conversely, a smaller proportion of indicators, such as "Observable changes in the behaviour of citizens towards climate neutrality" and "Behavioural changes among tenants could lead to more sustainable lifestyles", correspond to the later stages of behavioural change (Action and Maintenance). This highlights that the prevailing focus of climate actions related to behavioural change, whether directly or indirectly, is on raising awareness or fostering intention (e.g., through participation and engagement) rather than on sustaining action and long-term maintenance of pro-environmental behaviour.

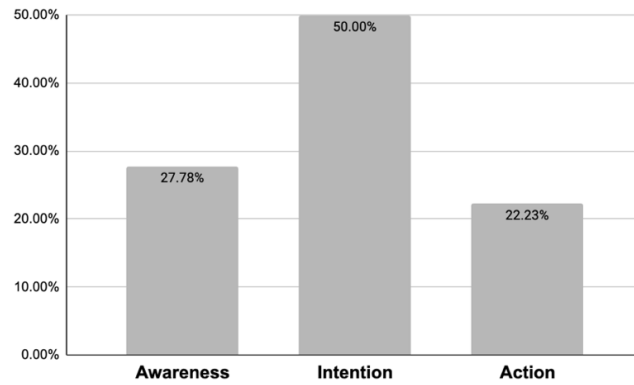


Figure 2. Bar chart showing the distribution of customised Long-term Non-GHG indicators selected by cities across the stages of behavioural change

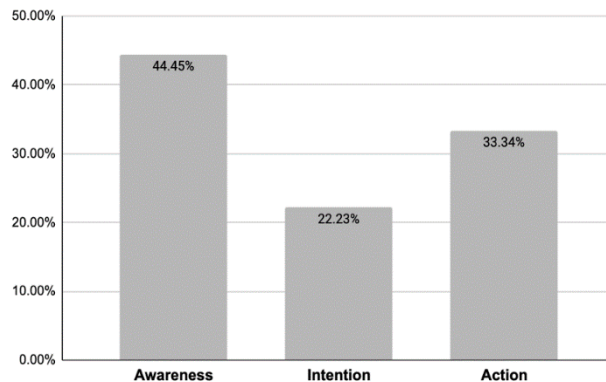


Figure 3. Bar chart showing the distribution of customised Co-benefit indicators selected by cities across the stages of behavioural change

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This pattern was reaffirmed upon further analysis of the indicator selections based on the 6 GHG emission domains the cities used to categorise their planned interventions: (1) All vehicles and transport, (2) Consumption of electricity generated for buildings, facilities, & infrastructure, (3) Consumption of non-electricity energy for thermal uses in buildings & facilities, (4) Agriculture, Forestry, and Other Land Use (AFOLU), (5) Multi-sector waste management and disposal, and (6) Industrial Processes and Product Use (IPPU). The emission domain category *Consumption of electricity generated for buildings, facilities, & infrastructure* accounted for the highest number of indicators that were directly or indirectly linked with behavioural change (22.22%). For instance, under this emission domain, the indicator “*level of sense of agency among stakeholders and residents*” has been used to track the distributed leadership and agency, activated through place-based civic contracting. On the contrary, the domains *AFOLU* and *IPPU* accounted for the least number of indicators (accounting for 13.58% each), which might be due to the corresponding lower number of actions planned by cities in those domains. Figure 4 illustrates the distribution of behavioural change across the 6 emission domain categories. Furthermore, Figure 5 illustrates the stages of behavioural change addressed in each emission domain. It is observed that across all the emission domains, indicators linked with the Awareness and Intention stage are significantly higher in number than those associated with the Action stage.

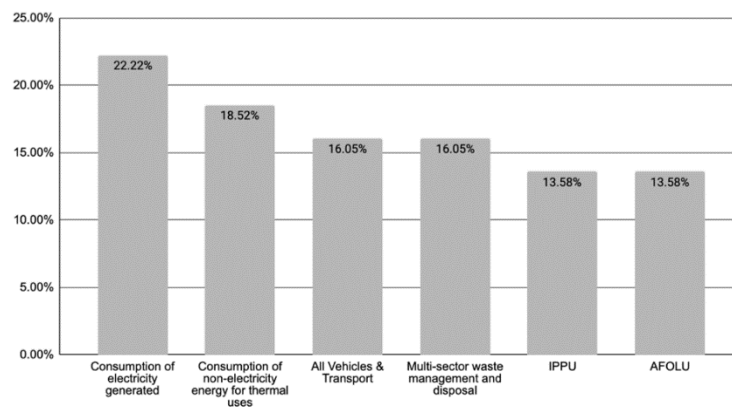


Figure 4. The distribution of Behavioural change indicators across Emission Domains

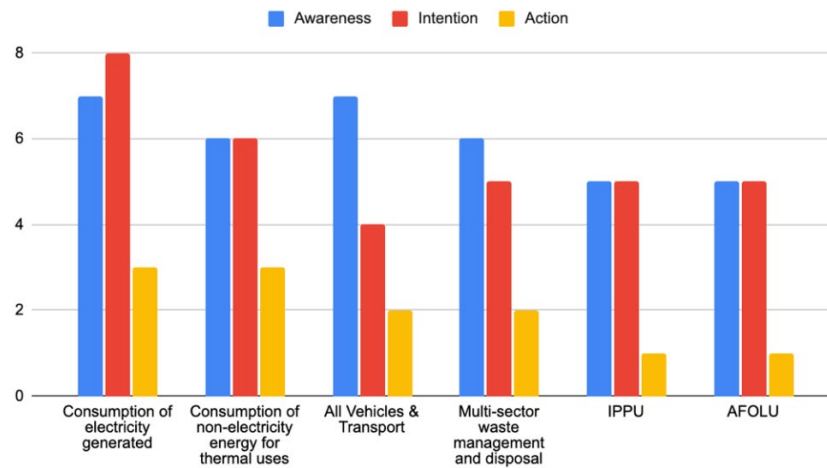


Figure 5. Bar chart showing the number of indicators corresponding to the behavioural change stage per Emission Domain

Lastly, the behavioural change indicators were also analysed from the lens of 6 systemic levers of changes (provided to cities with the project guidelines) used by cities to categorise their climate interventions (Figure 6): (1) Democracy and Participation, (2) Social Innovation, (3) Governance and Policy, (4) Learning and Capabilities, (5) Technology and Infrastructure, (6) Finance and Fundings.

The Systemic Lever “Democracy & Participation” emerged as the most frequently occurring systemic lever (accounting for 30.14% or one-third of all indicator selections) related to behavioural change. The frequent occurrence of indicators related to citizen participation and engagement, such as “*percentage of citizens participating in energy-related initiatives*” and “*number of community engagement activities*”, demonstrates the strong emphasis placed by cities on fostering behavioural change through interventions that promote citizen involvement and collective action. The lever “Social Innovation” also emerges to be central to cities’ behavioural change strategies, accounting for 21.92% of selections. For instance, indicators such as “*Share of citizens with eco-friendly behaviours (collective mindset directed towards achieving climate neutrality)*” are used to measure the success of social innovation initiatives within the transport and mobility sector to foster communication and dissemination towards a collective mindset for achieving climate neutrality. Another example of measuring behavioural change through social innovation is the indicator “*Social spectrograph (actively involve stakeholders and citizens through participatory solutions)*” to monitor progress on social justice, inclusivity, just transitions, and the acceleration of socially peaceful change towards net-zero through broader acceptance of solutions. There is also a significant focus across cities to foster behavioural change through the systemic lever of “Governance & Policy” (occurring at 19.18%). For instance, a Nordic city is focusing on the “*development of strategic approaches for broader work across the city with business, civil society and citizens to significantly decrease the climate impact of consumption, lifestyle and behaviour*”, by activating its Governance & Policy lever. It aims to monitor the “*climate impact per capita of consumption*” (in t CO₂ equivalents/year) to assess behavioural changes among citizens towards the adoption of pro-environmental lifestyle choices. The lever of “Learning & Capabilities” (occurring at

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17.81%) has also been significantly used to drive behavioural change among citizens, especially at the stage of awareness. For instance, a southern European city is focused on building social awareness for organic waste and biowaste exploitation, and on promoting circular business models and commits to monitor the progress of their activities by measuring the “*number of citizens engaged through [their] Pilot activities*”.

On the other hand, the focus on the systemic levers of “Technology & Infrastructure” and “Finance & Funding (each occurring at 5.48%) among cities is relatively lower when it comes to fostering behavioural change towards climate neutrality. In this context, cities are measuring the “*number of users of public transport system*” as a metric to assess progress made in the technological and infrastructural development within the city’s transport and mobility sector.

Some progressive cities use the “Finance & Funding” lever of change to plan activities aimed at increasing the share of case organisations’ budget dedicated to nudging of sustainable commuting among employees, monitoring “*incentives/work benefits offered by the employers (value/employee)*”.

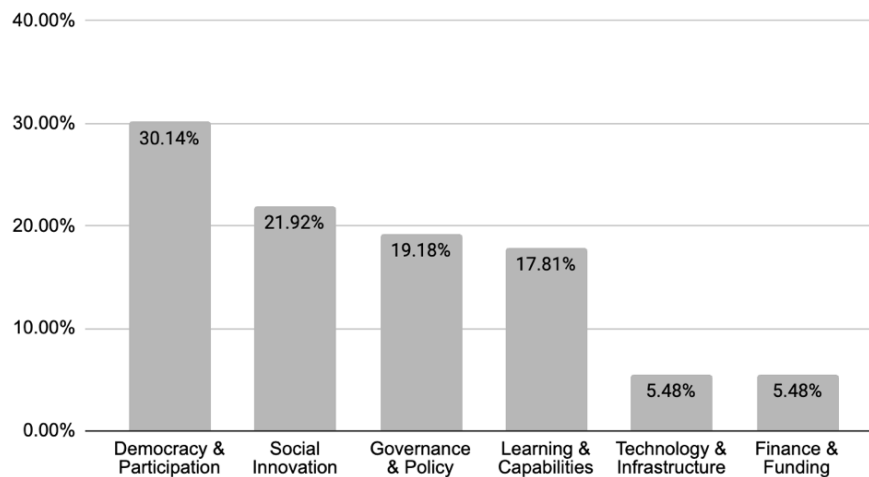


Figure 6. Bar chart showing the distribution of behavioural change indicator selections across systemic levers

Upon further evaluating the systemic levers in terms of the stages of behavioural change (Figure 7), the dominance of the behavioural stage of Awareness remains true for the levers “Democracy & Participation”, “Social Innovation”, “Governance & Policy” and “Learning & Capabilities”. However, interventions categorised by cities under the levers “Technology & Infrastructure”, and “Finance & Funding” are only linked with indicators that relate to the Intention and Action Stages of behavioural change.

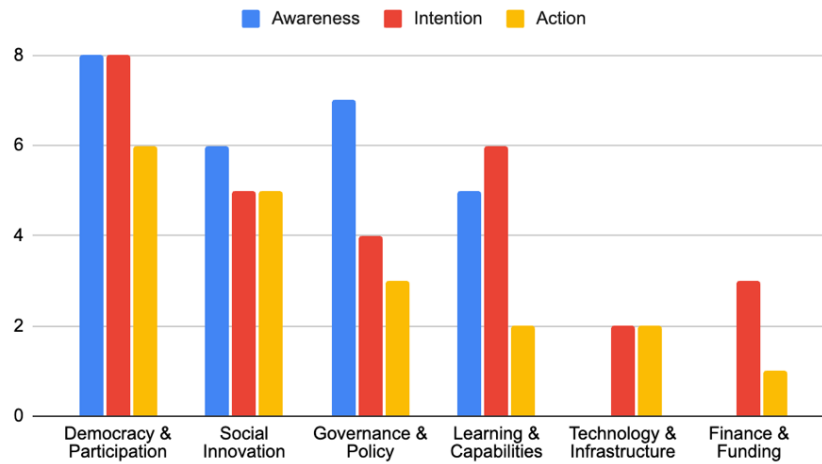


Figure 7. Bar chart showing the occurrence of the stages of behavioural change per systemic lever

6. DISCUSSIONS

The categorisation of the indicators in terms of the stages of behavioural change and emerging patterns with respect to GHG emission domains and systemic levers thus offers novel knowledge to assess the stage of behavioural change. Additionally, the application of behavioural change models in systemic climate transitions is a novel contribution to the transdisciplinary literature on behavioural change in systemic transformations, which extends beyond the focus on the individual.

This study not only assesses the evidence of how behavioural change is being planned, monitored and enabled by to-be-climate-neutral municipalities in Europe, but also presents an application and adaptation of the TTM to study behavioural change (beyond the individual level) within systemic climate transitions in cities. While the critical need for addressing behavioural change in systemic climate transitions has been well established in the extant transdisciplinary literature, this study identifies indicators of behavioural change selected by 39 cities and presents novel insights into the stages of behavioural change they are linked to. Furthermore, it also discusses the relations across behavioural change indicators, emission domains and systemic levers used to categorise climate actions.

The cities within the project not only selected standardised indicators provided within the project but also proposed customised indicators that are more suited to their contextual needs. Behavioural change indicators proposed by cities are primarily linked to the early stages of the adapted TTM (i.e., Awareness and Intention). This indicates that climate interventions planned to foster behavioural change in cities are currently focused on shallow scaling strategies to build awareness or to nudge citizens to adopt pro-environmental behaviours. Furthermore, it is observed that cities are primarily focused on fostering behavioural change through bottom-up systemic levers such as “Democracy & Participation” and “Social Innovation”. This insight also complements several case examples emerging from the project of Social Innovation as a driver for behavioural change (Bresciani et al., 2025). On the contrary, it is seen that the Systemic levers “Technology & Infrastructure” and “Finance & Funding” only correlate to behavioural

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change indicators linked to the Intention and Action stages. Thus, cities perceive such levers to be more effective towards driving “action” or “maintenance” of desired behaviours rather than building awareness or intention towards pro-environmental behaviours.

When assessing behavioural change indicators in relation to emission domains, “consumption of electricity generated for buildings, facilities, and infrastructure” emerges as the most frequently represented domain. Several indicators within this category, for example, “share of citizens with eco-friendly behaviours [collective mindset directed towards achieving climate neutrality]”, primarily address lifestyle and consumption choices of citizens. By contrast, relatively few behavioural change indicators are associated with the domains of IPPU and AFOLU, according to the cities’ indicator selections. While this suggests that certain emission domains are more likely to incorporate behavioural change interventions, the evidence remains limited, as the indicators themselves do not exhibit characteristics that clearly link them to specific emission domains.

Assessing the indicator selections by city shows that out of the 39 cities examined, 18 address only a single stage of behavioural change, and 13 address up to two stages. On the other hand, the only cities to address all 3 stages of behavioural change include 1 Finnish and 2 Swedish cities. Moreover, by examining the geographical distribution at the European level (Figure 8), Northern Europe, particularly comprising cities from Finland and Sweden again, monitors the highest number of behavioural change indicators, summing up to 15 indicators used across the 5 cities. This pattern shows a strong focus of the Nordic European countries on behavioural change to achieve climate neutrality. In fact, the distribution of these indicators across the 3 stages of behavioural change is fairly even, as seen in Figure 8, indicating an advanced level of preparedness in these countries to address the behavioural dimension of climate transitions across all the stages.

On the other hand, Southern Europe accounts for 11 behavioural change indicators selected. Unlike the Nordic cities, the distribution of the indicators in these southern European cities is significantly higher towards the Awareness (with 4 indicators) and Intention (with 5 indicators) behavioural stages as compared to Action (2 indicators). For the remaining European cities included in this study, no clear pattern emerges, as the numbers in Eastern, Western, and Central Europe are relatively small and geographically dispersed.

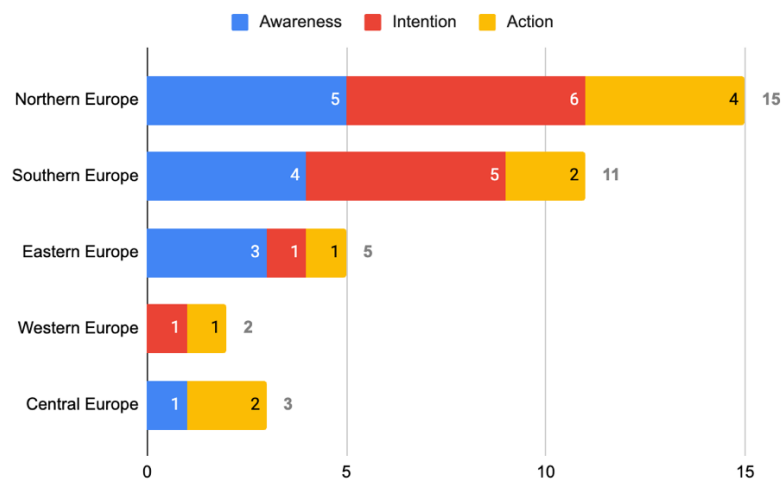


Figure 8. Distribution of behavioural change indicators across European regions

7. CONCLUSION

This study presents novel insights on the assessment of behavioural change in systemic transformations by categorising indicators of climate interventions chosen by European cities for climate action monitoring and evaluation, based on an adaptation of the Transtheoretical Model of Change (TTM). The indicators' selection of the 39 cities provides evidence of how cities are planning to monitor the behavioural change of citizens within the context of systemic change for reaching climate neutrality. The classification of indicators into Awareness, Intention and Action supports cities in structuring the assessment of the implications of planned climate actions on the behaviour of their citizens, helps shape climate policy that incorporates behavioural insights (Rutter et al., 2017), and gauges how cities are positioned in their journey to foster long-term behavioural change of citizens within systemic transformations (Newell et al., 2021). The study also provides key insights emerging from analysing patterns of behavioural change indicators, emission domains and systemic levers. This enables cities to develop not only soft climate adaptation strategies (Sovacool, 2011) but also to foster deep scaling of behavioural change through hard and soft policy measures or normative influence within a systemic approach.

This study offers a theoretical contribution to the emerging transdisciplinary literature on mitigation, while addressing the pressing needs of cities striving towards climate neutrality. Nonetheless, certain limitations must be acknowledged. First, data is limited to Europe: further testing and adaption might be needed in different geographical and cultural contexts; however, the categorisation and insights presented here may also prove valuable for analysing cities globally. Second, the evidence is based on cities' initial proposals, which represent early-stage plans that are likely to evolve over time. Future research should therefore build on post-implementation evidence to assess the extent to which cities succeed in realising behavioural change and how the indicators support municipalities in learning from actions. Additionally, future directions of research may expand on how the level of preparedness of cities to address behavioural change correlates with the stages of behavioural change they address through their climate actions. Lastly, the proposed categorisation may be further expanded to assess the degree of dependence (for the success) of climate interventions on the various stages of behavioural change of citizens.

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