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RAPID DECARBONISATION OF CITIES BY ADDRESSING BEHAVIOURAL FAILURES? A CRITICAL REVIEW OF POLICY INTERVENTIONS

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Abstract

While many of the interventions to reduce carbon emissions target market failures, little attention is given to behavioural failures. This study investigates to what degree cities, which have taken a central role in global decarbonisation efforts, already incorporate findings from behavioural economics in their policy interventions. The 'traditional taxonomy' for policy intervention, represented among others in the work of the IPCC, is taken as a benchmark for assessing city's decarbonisation interventions in the areas of building energy efficiency and transportation. Based on an extensive literature review and empirical data of urban climate networks, the study finds that market failures in adopting low-carbon technologies largely dominate the framing of policy interventions. Based on few examples of non-traditional interventions addressing behavioural failures, an alternative taxonomy to frame decarbonisation policy is discussed.

1. INTRODUCTION

There are several drivers behind the increasing focus on climate action in cities, including rapid urbanization, increasing (urban) GHG emissions, the failure to achieve tangible outcomes at national or even global level, and the recognition that 'subnational governments may tailor actions and policies to people's needs, with an easier identification of priorities and difficulties as they are closer to citizens than more centralized administrations' [1, p. 1183]. It can also be observed that climate governance is often viewed and implemented as a 'top-down' policy approach, neglecting important knowledge, opportunities and synergies at the city level (or 'bottom-up' approach) [2], [3]. It is ultimately at the local level that low-carbon energy technologies are (or not) taken up and, importantly, people behave, misbehave or fail to behave with respect to climate change mitigation (e.g. via energy conservation measures). While most of the policy efforts to address climate mitigation have been heavily devoted to technology change, the potential of cities to work with behavioural change remains largely untapped [1], [4]–[6].

While there are strong indications that behavioural change has the potential to reduce city-level emissions quickly and at low costs [7], [8], the scientific understanding of frameworks and methods to assess policy interventions in relation to cognitive factors that frame people's economic decisions is still limited in scope [9]–[12]. In this particular case, there is a lack of studies systematically addressing interventions that explicitly aim to tap the behavioural mitigation potential at a city level. Moreover, there rarely is a clear distinction between 'traditional' policy approaches to change behaviour (e.g. energy pricing, legal incentives, provision of infrastructure) and interventions that explicitly tackle behavioural failures (e.g. heuristics, biases, illusions and misconceptions in decision making) and are thus based on findings from behavioural science and behavioural economics. There is a substantial risk in omitting behaviour both as underlying driver and source of climate mitigation because '[p]olicies for mitigating climate change or reducing the harm that it causes inevitably make assumptions about the behaviour of the people who must execute or respond to those policies. Unless those assumptions are realistic, the policies may fail' [12]. By focussing on market failures, the traditional policy interventions ignore a large number of 'behavioural failures' [13]–[16] that may be behind undesired behaviour.

However, first findings from behavioural economics 'illustrate that it would make good sense to expand the inventory of strategies for environmental behaviour change' [17, p. 353]. In the emerging field of (green) behavioural economics attempts are made to integrate behavioural and economic aspects in the design of policies for the adoption of sustainable energy-related behaviours [10], [11], [13], [17]–[20]. Options under study include for instance the use of 'green defaults' [19], [21], [22], 'real-time feedback' to households on energy use [23], [24], approaches based on 'social and community norms' [25], and more general, the targeted utilization of nudges [17], [18], [26].

The objective of this paper is to critically review the nature and orientation of city-oriented climate and energy interventions. A policy taxonomy is used to assess the degree to which cities already make use of non-traditional policy interventions, and to what degree these interventions explicitly incorporate insights from behavioural economics. The working hypothesis is that virtually none of the interventions in cities explicitly address behavioural failures and, thus, the technology policy paradigm still prevails.

2. CONCEPTUAL FRAMEWORK

In order to better understand the reasons behind behavioural failures and to develop effective interventions addressing urban decarbonisation, it is important to also understand how people make decisions and which factors affect these processes. The following sections briefly

introduce different concepts that are used to frame the research at hand.

2.1.Models for decision making

Rational choice theory is the standard model for decision making in neoclassical economics[1] [28]. In his seminal piece 'A Behavioural Model of Rational Choice' Herbert A. Simon [29] provides a concise description of an economically rational decision-maker: 'This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organized and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale.' [29, p. 99] This description of the economic man was not only criticised by Simon, who introduced the concept of 'bounded rationality' [29], but by various economists and other social scientist after him [30], [31].

In fact, there are various psychological models of decision-making that can capture behaviour that is not in line with the rational choice model outlined above. The Theory of Planned Behaviour is among the most widely used psychological models of decision-making. It links attitudes and subjective norms via intentions to behaviour, taking into consideration the 'perceived behavioural control' [32], which is understood as 'beliefs concerning the controllability of the behaviour and efficacy expectancies' [33]. The question of how controllable decisions actually are, is present in Kahneman's popular two systems theory, in which system 1 is responsible for fast, automatic, frequent, emotional, stereotypic, subconscious decisions, while system 2 does the slow, effortful, infrequent, logical, calculating, conscious work [34].

When comparing the rational choice model of mainstream economics to empirical studies of behaviour, it becomes quickly clear that the rational choice model is virtually never true for individual decision-makers, a shortcoming to which economists have responded in two ways. First, departures from the perfect market ideal can be framed as market failures and market imperfections. In the context of climate change mitigation and energy, frequently cited market failures include unpriced externalities (CO_2 emissions), R&D spillovers (low-carbon technologies), the principal-agent problem (energy efficiency investments in tenant-occupied buildings), and various lacks of information [14]. Once these market failures and imperfections are fixed, so goes the theory, rational agents ensure an efficient market outcome. Second, it was claimed that violations of the rational choice model at the individual level do not affect 'rational expectations' in macroeconomic models that are still best designed as if actors were economically rational [35], [36].

2.2.Behavioural failures

Behavioural economics departs from the view that economically irrational behaviour constitutes a market failure that needs fixing, and reframes it as behavioural failure – or rather a characteristic of human decision-making [37], [38]. Due to systematic occurrence of behavioural failures they may also lead to biases at the aggregated level that can be predicted to a certain degree. The difference between market and behavioural failures has been shown in the specific context of the 'energy efficiency gap' [15], in a wider environmental policy context [13], and for consumer decision-making in general [16].

Behavioural economics, hence, deals with behavioural failures, which are framed as systematic limitations of (economically) rational decision making, including bounded rationality, bounded willpower, and bounded selfishness [39]. Behavioural economics is the

[1] For a more comprehensive review of decision-making models in the context of residential energy use see [27].

umbrella for several branches, including prospect theory, intertemporal choice, norm-based behaviour, and heuristics [40]. Table 1 provides short explanations of some key concepts in behavioural economics. Nudging – another popular behavioural economics concept – is not mentioned in this list as it is 'arguably not a theory per se – only an empirical application of pioneering work in behavioural decision theory to public health or environmental problems.' [17, p. 353]

Behavioural economics is not restricted to the conceptual level. In the specific context of climate change mitigation and energy, various empirical studies have shown economically irrational behaviour. People stick to their standard electricity tariffs even though they are willing to pay for a greener tariff or the green tariff would even be cheaper [19], [22]; people reduce their use of energy once they know how much their neighbours use [25]; people have self-control problems when choosing appliances [41]; and they may even be affected by political ideology in their energy efficiency choices [42].

Table 1: Overview of some key concepts in behavioural economics[2]

Concept	**Brief definition in the context of decision-making**
anchoring	Different starting points may lead to different estimates in a decision-making situation. These estimates are biased towards the initial value, which serves as an 'anchor' [44, p. 1128].
bias	Biases are systematic and predictable behavioural failures that are caused by heuristics (see below) for making uncertain decisions. [44]
default(s)	Default rules establish what happens if people do nothing at all. People tend to stick to defaults as they may perceive them as implicit suggestions or endorsements by experts, as they procrastinate active decision making, and as they treat them as reference points, which tend to stick due to loss aversion. [19]
hyperbolic discounting	People tend to make decisions based on time-inconsistent discount rates, discounting gains in the distant future at higher rates than gains in the near future. [45], [46]
framing	The same choice can be framed in different ways and people tend to change their decisions depending on the framing. [47]
heuristics	Heuristics are suboptimal but practical decision-making methods, which 'reduce the complex tasks of assessing probabilities and predicting values to simpler judgemental operations' [44, p. 1124].
loss aversion, risk aversion	People tend to value losses higher than gains and certain gains higher than uncertain gains with the same expected value. [48]
nudging	Closely related to framing, a nudge is an aspect of the choice architecture that changes people's behaviour in a predictable way without forbidding options or changing their economic incentives. [26]
salience	If in the framing of a decision a choice aspect stands out, i.e. is salient, it strongly affects decisions. [38]
satisficing	In many situations it is impossible to optimize decisions, or the 'computational cost' for that is just too high. Hence, people tend to choose options that meet certain criteria, but that are not necessarily optimal. [49]
social norms	'Social norms are customary rules of behaviour that coordinate our interactions with others.' [50] Social norms may be the reason for departure from rational choice. [51]

3. METHODOLOGICAL APPROACH

This policy-oriented study had both conceptual and exploratory elements, combining the development of a taxonomy for policy interventions with the search for concrete examples of non-traditional policy interventions at the city level. The focus of policy-oriented research is on actionable factors or variables [52] such as policy interventions, which are also the subject of policy analysis and evaluation [53], [54]. Following Wilson and Dowlatabadi policy interventions include 'any regulation, policy, program, measure, activity, or event that aims to

[2] It becomes quickly clear that this compilation is not exhaustive when browsing the Wikipedia entry 'List of cognitive biases' with many more than hundred biases [43].

influence behavior' [27]. The general research approach was implemented in four steps.
First, a taxonomy of 'traditional' policy interventions was synthesised and attempts to frame 'non-traditional' interventions were reviewed. The synthesis of the traditional taxonomy was based on a literature review of frameworks for (urban) climate interventions, including the work undertaken by the IPCC and the Global Energy Assessment. The frameworks for non-traditional interventions were extracted from the (green) behavioural economics literature.
Second, several urban climate and energy networks and related databases of climate and energy interventions were analysed. Policy interventions being reported to (but also fostered by) these networks were screened and related to the taxonomies mentioned above. This analysis focussed on the way the networks frame and classify climate and energy interventions themselves in order to investigate to what degree they are able to capture non-traditional interventions.
The researched networks included the C40, Compact of Mayors, Covenant of Mayors, Energy Cities and the Carbon Neutral City Alliance (see Table 2 and Appendix A for brief desciptions). While the networks put great emphasis on measuring CO_2 emissions, reporting them, setting reduction targets and developing strategies and action plans, this study focussed on specific interventions and how they are framed in each of the respective networks. Only policy interventions related to household energy use in residential buildings and transport were included, in turn excluding all adaptation actions and mitigation in the sectors industry, waste, and land-use changes.

Table 2: Urban climate networks, their scope and data sources used in this study

Organization	**Scope**	**Data sources**
C40	80 large international cities	Series of guidebooks with ca. 50 good practice cases(online) [55]
Carbon Neutral City Alliance (CNCA)	17 large international cities	Framework document [56]
Compact of Mayors	504 international cities	Online-database 'carbonn Registry' [57]
Covenant of Mayors	6 700 European cities	Online-database with 3 200 self-reported city actions [58]
Energy cities	> 1 000 European cities	Online-database with 485 good practice cases [59] 30 Energy Transition actions [60]

Third, examples for urban climate policies that explicitly address behavioural failures were identified and further elaborated. All examples stem from the data sources mentioned in Table 2. These data sources were investigated for several conceptual and technical expressions associated with non-traditional interventions. The list of expressions was based on the conceptual framework (see Table 1). The examples for non-traditional policy interventions were briefly summarized and analysed with respect to their behavioural components.
Finally, possibilities to adapt or expand the predominant traditional taxonomy to better accommodate and emphasize non-traditional behavioural policies were discussed.

4. RESULTS – FRAMING URBAN DECARBONISATION INTERVENTIONS

4.1.Literature review: Taxonomies of policy interventions for decarbonisation

IPCC Assessment Reports
Based on previous work [61], the IPCC differentiates in its fifth assessment report (AR5) between various policy interventions in the following categories: economic incentives (incl. emissions taxes and permit trading and subsidies), direct regulatory approaches, information programmes, government provision of public goods and services, and voluntary actions [5]. This basic taxonomy is used throughout AR5 for policies and subsequent assessment chapters

at both the national and subnational level and in various economic or end-use energy sectors. It can be found in a similar form in IPCC's Special Report on Renewable Energy Sources [62, p. 883]. The elaboration of the taxonomy as such (see Appendix A) does not refer to behavioural failures, and this is largely true for the application of the taxonomy in different climate policy areas.

In the case of policies for energy efficiency in buildings, which is particularly relevant in an urban context, most interventions discussed in AR4 and AR5 can be clearly categorized according to the IPCC taxonomy presented above (see tables in [63, pp. 432–434], [64, pp. 716–717]). Regulatory approaches include building codes, energy performance standards for appliances, procurement regulation and mandatory labels and certificates. Economic instruments include various taxes, energy efficiency obligations and white certificates, grants, subsidies and soft loans. In addition, voluntary and negotiated agreements and awareness raising/ information campaigns are listed. There are some instruments that cannot be clearly categorized. Mandatory energy audits can both be seen as regulation and informative instrument, and the same holds true for mandatory labelling. Moreover, energy efficiency obligations and white certificates create economic incentives but are rooted in regulation.

While the IPCC compilations of policies for energy efficiency in buildings do not explicitly refer to behavioural failures, some behavioural failures are implicitly addressed in further specifications of the instruments. First, it is mentioned that informative instruments like labelling or energy audits are more effective in combination with regulation or fiscal incentives [63, p. 434]. It is a well-established finding that consumers underinvest in energy efficiency (even if they know that it might pay off), since they tend to discount future gains more than short-term expenses (hyperbolic discounting), which is economically irrational[3]. Mandating energy efficiency investments or providing fiscal incentives are then strategies to overcome this behavioural failure, once the knowledge about potential investments is established. Second, the policy compilations mention 'individual feedback' about energy use [64, p. 717] and 'detailed billing and disclosure programmes'[63, p. 434]. Both are certainly targeted at filling information gaps (a standard market failure), but can also be used to go beyond the mere provision of energy use data, e.g. by introducing aspects of gamification [66] or reference to social norms [25].

However, in the analysed applications of the IPCC taxonomy no *explicit* reference to behavioural failures was found. The IPCC was aware of this research gap, which is explicitly highlighted in AR5: 'More research that incorporates behavioural economics into climate change mitigation is needed. For instance, more work on understanding how individuals and their social preferences respond to (ambitious) policy instruments and make decisions relevant to climate change is critical.' [5, p. 258]

Global Energy Assessment

The Global Energy Assessment (GEA) states in its policy chapter that in 'addressing […] energy-related policy goals, governments have various instruments available to them. While the potential options are numerous, in a generic sense, policy is usually manifested as:

- direct public ownership or control;
- regulations and standards;
- information, education, and public engagement to promote voluntary actions;
- financial charges, such as taxes and fees; and
- subsidies, such as grants, low-interest loans, and rebates.' [67, p. 1556]

This taxonomy is very close to the IPCC version, only that economic instruments are split into

[3] Additional explanations for underinvestment include hidden costs and discount rates that are higher in reality than the ones assumed in models [65].

two categories for incentives and disincentives, that voluntary actions are merged into the information category, and that 'direct public ownership or control' slightly differs from the IPCC formulation 'government provision of public goods and services'.
Just like the IPCC taxonomy, the GEA version is in principle open for policy interventions addressing behavioural failures. When further analysing the sectoral energy policies suggested in the GEA, it becomes clear that behavioural failures are – with one exception – not addressed explicitly. The policy compilations for renewable energy [68, p. 877] and urban transport policy [4, pp. 1372–1375] are particularly centred on market failures and top-down policy approaches, whereas energy efficiency in buildings is a different case.
While the suggested policy portfolios for 'appliances and devices' and 'buildings' in the policy chapter of the GEA include only regulatory and economic instruments as well as labels [67, pp. 1593–1595], the chapter dedicated to energy end-use in buildings gives explicit consideration to behavioural failures when discussing policy interventions [69]. It lists 'Cultural/ behavioral barriers' and suitable policy instruments as remedies [69, p. 732]. Behavioural barriers are also referred to as 'behavioral and organizational non-optimalities' and include a rather diverse collection of barriers to energy efficiency, that are somehow connected to behaviour, including among others the 'tendency to ignore small opportunities for energy conservation', 'non-payment and electricity theft', 'tradition, behavior [!], lack of awareness, and lifestyle' as well as 'corruption' [69, p. 699]. Two examples of behavioural failures that are discussed more in depth are high discount rates for future benefits of energy efficiency investments and the framing effect in providing feedback about energy use. Surprisingly, behavioural failures are not reflected in this chapter's categorization of policy instruments, which follows the IPCC structure. The actual compilation of various policy instruments is even a direct (and only marginally updated) copy from IPCC's AR4 (compare [63, pp. 432–434], and [69, pp. 728–731]).

The traditional taxonomy of policy interventions for urban climate mitigation and energy
Before turning to the behavioural economics literature and its framing of policy interventions in the field of climate mitigation and energy, the synthesis of the taxonomies presented above shall be defined here as the 'traditional taxonomy'. It includes:

- Regulation (incl. bans, mandates, standards),
- Economic instruments (incl. taxes, fees, subsidies, preferential loans),
- Information (incl. advice, promotion, campaigns, guidance), and
- Provision of public goods (incl. infrastructure).

Insights from Behavioural Economics
Behavioural economics provides several examples for non-traditional behavioural policies to address climate change (e.g. green defaults or reference to social norms), but there is no widely accepted taxonomy for these interventions. Just as this paper makes a slightly fuzzy difference between traditional and non-traditional interventions, Bamberg et al. (2011) differentiate between 'hard' and 'soft' policy measures (to reduce car use). Soft measures include 'psychological and behavioural strategies', which are not subdivided any further [70, p. 228].
The attempt by Gillingham et al. [14] to separate policies addressing market failure from those addressing behavioural failures in a systematic way (see Appendix C for details) does not result in a workable taxonomy, either, as the policy options to address behavioural failures are kept at a very general level, namely 'education, information, product standards' [14, p. 605]
Pete Lunn [71] takes a more specific look at potential regulation to warrant three important characteristics of consumer choice, namely simplicity, convenience and salience. Choice

overload is a common phenomenon in various areas of consumption (e.g. electricity tariffs) and, while not uncontroversial, it is possible to mandate simplified information and choice. Similarly, also the choice *process* can be regulated, which targets the convenience of decision-making. Convenient options are more likely selected, with sticking to defaults being the most convenient option of them all. Finally, product or service attributes can be more or less salient to consumers. These attributes can again be influenced by regulation that aims at making important features (e.g. tax components of the price) more salient. [71]
The most systematic behavioural-economic taxonomy of policy interventions is provided in the report 'Behaviour Change' published by the British House of Lords [72]. Here the traditional taxonomy is translated into the perspective of the individual (see Appendix D). Regulation becomes 'elimination of choice' and 'restriction of choice', economic instruments are framed as 'fiscal disincentives' and 'fiscal incentives', information is captured by 'persuasion' and 'provision of information', and the provision of public goods is partially reflected in the novel category 'changes to physical environment'. The latter is presented in this framework as one way to change the choice architecture and 'nudge' people to the desired behaviour. Other nudging categories are 'changes to the default policy' and 'use of social norms and salience'. It is important to note that changes to the choice architecture often require regulation to enact them. [72]
The review of behavioural economics literature presented above makes clear that there is no standard way to frame policy interventions that address behavioural failures. One common factor is that a bottom-up perspective is taken, i.e. the framing is organized from the perspective of the individual actor and not the policy-maker. Moreover, addressing behavioural failure may imply both a different use of traditional interventions, and the use of completely different interventions.

4.2.Interventions for decarbonisation in urban climate networks

In addition to insights from literature, it is important to understand how interventions are framed and motivated in practice. The following review of interventions reported in the context of urban climate networks is compared to the traditional framework mentioned above. Moreover, cases of explicit reference to behavioural failures are researched. Three cases are described more in depth (section 4.3).

Carbonn registry (Compact of Mayors)
By the end of 2015 ca. 500 cities and regions had reported 6 200 actions and action plans in the carbonn registry – most of them participants in the Compact of Mayors [73]. The categorization of climate actions in the registry closely corresponds to the traditional taxonomy, including explicit categories for 'Education/ Awareness', 'Regulatory' action and 'Fiscal/ Financial mechanisms' (see Figure 1).The additional categories 'Public participation/ Stakeholder engagement', 'Assessment/ Research' and 'Organization/ Governance' are important procedural aspects rather than direct interventions.

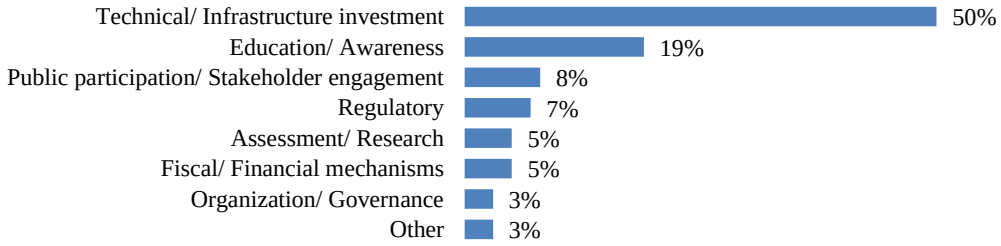

Figure 1: Categorization of methods of climate action based on [73, p. 23][4]

In principal there are several categories that may include interventions addressing behavioural failures. Figure 1 suggests, however, that the focus is on technical interventions. This is further supported by the keyword search in the carbonn-database, which resulted in only a handful of interventions that explicitly mention some of the search items (in this case 'default', 'nudge', 'habit' and 'trust'), and at the same time have the potential to address behavioural failures. These interventions include for instance the use of 'nudges' in mobility management (Lund, Sweden), the introduction of 'defaults' for 2-sided printing and paperless billing to reduce paper consumption (Vancouver, Canada), the registration of 'accredited service providers' for solar water heaters to create 'trust' of customers (Cape Town, South Africa), and a long-term commitment campaign with 70 families to change 'habits' (Gävle, Sweden).

Covenant of Mayors

The Covenant of Mayors offers an online database with 3 200 self-reported actions from participants' Sustainable Energy Action Plans (SEAP). These so-called 'Benchmarks of Excellence' are categorized by (technology) sector and, within the respective sector, by area of intervention and policy instrument (see Appendix F). Interventions directly addressing households and individuals occur mainly in the sectors 'Residential buildings' and 'Transport'.

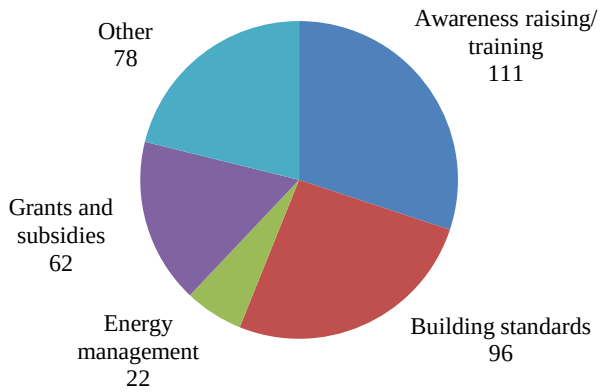

Figure 2: Overview of policy instruments in the sector 'Residential Buildings' (Author's illustration based on data from the Covenant of Mayors)[5]

The multitude of categories in the area of residential buildings (see Figure 2) does not necessarily reflect diversity in instrument use and can easily be fitted into the 'traditional

[4] The original graph is based on 6 181 climate actions and also lists 'Policy/ Strategies/ Action Plans' (26%), which has been removed here in order to focus on actual climate actions.

[5] The category 'Other' includes Energy management, Energy certification/ labelling, Energy suppliers obligations, Energy/ carbon taxes, Third party financing/ PPP, Public procurement, and Land use planning regulation.

taxonomy'. Among the 369 interventions addressing residential buildings only 26 are tagged as 'Behavioural change' interventions in the database. All of these interventions are in the category 'Awareness raising/ training' and include energy audits/ advice to households (17), energy efficiency campaigning (6) including promotional leaflets, awareness-raising in schools and events, as well as the training of municipal technicians (1)[6]. The keyword search for concepts related to behavioural failures did not identify any interventions in the area of residential buildings.
Of the 330 interventions in the sector 'Transport', 18% are self-reported as 'Awareness raising/ training' instruments[7]. Moreover, 154 interventions are reported in areas of intervention that mainly deal with behavioural change, including the promotion of a modal shift towards walking, cycling and public transport, eco-driving and car-sharing. While there seems to be significant emphasis on behavioural aspects, the keyword search for concepts related to behavioural failures returned only a couple of interventions (keywords 'habits' and 'life events'; see section 4.3 for examples). This suggests that interventions addressing behavioural aspects of transportation are mainly based on traditional approaches.

Carbon Neutral City Alliance (CNCA)
In its framework document the CNCA lists various levers, strategies and actions for long-term decarbonisation. They represent a 'synthesis of the processes, strategies, practices, tools, and institutional structures used by leading-edge cities worldwide to plan long-term, deep reductions in carbon emissions' [56, p. 2]. The four levers that are used to guide policy intervention in different areas are: voluntary actions, price signals, public investments and mandates. This reflects again the traditional taxonomy of policy instruments.
While most of the strategies and actions listed under the lever 'Voluntary Action' build on the simple provision of information, some actions go beyond the standard menu of education, raising awareness and sharing best practices. For the area of building energy efficiency, these actions include, for instance, energy use benchmarking programs and improved access of customers to energy use data, which aim at putting information about one's own energy use into the context of the 'normal' energy use in the respective social context. While not mentioned explicitly, these interventions address a behavioural failure, namely (social) norm-based motivation in energy use (see Table 1).
The keyword search of the CNCA framework document returned two fairly relevant examples (references to 'framing' and 'habits'). The first example, while not referring to a specific intervention, is about shifting the framing of interventions from decarbonisation to economic opportunities or collective achievements [56, p. 22]. The second example highlights a project to promote car-pooling called 'CHUMS – Changing Habits for Urban Mobility Solutions' [56, p. 95]. This project combines three different interventions, including a promotional car pool week to raise awareness and attract users; personalised travel plans to create knowledge of the transport needs of employees and to successfully match users; and a lottery to attract and retain users. While this mix of interventions addresses some classical market failures (lack of information and coordination), it also relates to the loss averse attitude of car-commuters, for whom the potential losses of a switch to car-pooling may loom larger than the gains connected to it.

[6] The number of actions does not add up to 26 because two actions are wrongly categorized and actually deal with waste separation and collection.
[7] In addition, the transport sector includes the following categories for policy instruments: Integrated ticketing and charging, Grants and subsidies, Road pricing, Land use planning regulation, Transport/ mobility planning regulation, Public procurement, Voluntary agreements with stakeholders and Other.

Energy Cities

The European association 'Energy Cities' runs an online database filled with best practices from their more than 1 000 member cities and towns. These cases are ordered according to the following categories: buildings, local energy resources, mobility, economy & financing, local governance and capacity building, and energy & climate strategy and policy (see Appendix E for details). This categorization is slightly problematic as several categories overlap. The main distinction at a policy level is made between financing instruments and local governance and capacity building, which includes cooperation, participation, networking, information, education, training and local energy agencies. The categorisation of interventions in the Energy Cities database is rather *ad hoc* and therefore difficult to compare to the traditional taxonomy. It mixes (overlapping) areas of interventions with types of interventions. Still it should in principle be able to capture interventions that address behavioural failures.

The results of the keyword search for concepts related to behavioural failures indicate a rather traditional approach to decarbonisation. Only a couple of interventions that relate to sought after concepts could be identified (keywords 'habits' and 'default'). The example for green defaults is presented below (section 4.3). With the keyword 'habits' a behavioural survey for 'The energy, climate change and air quality plan of Barcelona' was found [74]. While the research from Barcelona was rather extensive and included various aspects and elements (survey on energy use and intentions, interviews, diaries of energy routines), the 'priority actions' derived from this empirical work comprise standard measures, such as provision of information, awareness raising, advisory services, feedback, and benchmarking. No explicit links to behavioural failures are made.

C40

The C40 initiative has issued a series of eleven good practice guides for cities of various sizes and geographies to implement the Paris Climate Agreement. Each guide differentiates between specific policy approaches for the respective areas. The guides are mainly aimed at technological change (e.g. introducing bus rapid transit, expanding district heating, improving waste management). Some approaches targeting behavioural change can be found in the guides on 'Municipal Building Efficiency' and 'Transit Oriented Development' [55].

Interventions aimed at municipal building efficiency are classified into seven general approaches of which only energy efficiency advice, as well as raising awareness and promotion of behaviour change have the potential to address energy use behaviour of individuals [75]. The keyword search for behavioural failure-related concepts yielded a couple of results. The first, addressing the processing of smart meter information, is discussed below (section 4.3). The second example is about the uptake of district energy heating by households and building owners in Milan. The main barrier for the uptake of district heating was identified as the lack of trust in the technology, while potential market failures such as a lack of information or cost-effectiveness were ruled out. Accordingly, campaigns were designed to 'counter the image of district heating as an inefficient and outdated technology' and instead promote it 'as a critical modern energy system for reducing carbon emissions' [76, p. 11].

4.3.Urban climate policies addressing behavioural failures

In the following some examples for climate policies that address behavioural failures are presented in more detail. All examples stem from the keyword search in databases and documents presented above. For each of the examples, critical links to the conceptual framework and taxonomies are discussed.

Default electricity price plans

One of the most prominent examples for non-traditional urban decarbonisation interventions is the use of green defaults for electricity price plans. People tend to subscribe to the standard electricity mix because it is usually the default option. If green electricity is the default, people will use green electricity, not (necessarily) because it is green but because defaults tend to stick (see Table 1). A frequently cited example in literature is a southwest German utility in the small town Schönau, where even many years after the default electricity plan was changed to 'green' virtually all subscribers sticked to it – even though there was a large number of competing offerings after the liberalization of the market. [19], [22]

The keyword search in the Energy Cities database identified another example for the use of green electricity defaults, Geneva's utility *Services Industriels de Genève*, which introduced a new tariff structure in 2002 (see Table 3).

Table 3: New tariff structure of Geneva's utility Services Industriels de Genève [77]

Brand	Product description	Deviation from tariff base
VITALE BLUE (new default)	Electricity from hydropower	Tariff base – 0,6 €cts / kWh
VITALE YELLOW	Electricity produced entirely in Geneva	Tariff base + 1,2€cts / kWh
VITALE GREEN	Electricity from renewable sources	Tariff base +5 €cts / kWh
MIX (old default)	Electricity with various origins	Tariff base -1 €ct / kWh

One important aspect of the change in tariff structure is that the new (green) default is cheaper than the old default before the change (Tariff base), but more expensive than the old default after the change (MIX). The tariff base can be seen as an 'anchor' (see Table 1), which serves as a reference point for assessing the different options.

The result of making green electricity the default and anchoring the new tariff structure at the tariff base, was a drastic shift away from nuclear and thermal power generation, whose share dropped within one year from 30% to 9% [77].

Life events as salient triggers to shift from the status quo

The status quo bias is one expression of loss aversion, which is a feature of human decision making which has been shown in various experiments and field studies [78]. Outcomes of behavioural change are perceived as to some degree uncertain; and as long as potential losses are valued higher than gains, there is a systematic tendency to stick to the status quo [48]. One strategy to overcome the status quo bias is to target interventions at salient points in people's lives when they are vulnerable to change, such as when there are natural and significant changes to decision environments. This may include moving to another place, changing jobs, getting married or becoming parent of a child. [79], [80]

The search for 'life-events' in the database of the Covenant of Mayors identified two examples for interventions targeted at salient trigger points in people's lives. The 'Go!Family' campaign of Munich addresses young families in the first year after the birth of their child. Parents can make use of three different subsidies to modes of transportation that are alternatives to car-ownership: free testing and subsidised purchase of children transport bikes, a one month ticket for the local public transport system, and/or one year free membership in Munich's car-sharing system STATTAUTO. Due to the large uptake of the offering the campaign was institutionalised after an initial test period.[81]

A similar approach was taken by the municipality of Gdynia, which was involved in a three year EU project called SEGMENT. Within the project different marketing approaches addressing travel behaviour of specific groups of people (segments) were developed and

tested. A core idea of the project was to capitalise on salient life events, such as starting school, changing jobs, and becoming parent. [82]

Smart feedback and bounded rationality – training facility managers to use energy use data
Smart meters offer new opportunities regarding feedback about energy use. In order to reach reductions in energy use, it is, however, critical how the feedback is presented and used. Some sort of feedback is necessary for energy savings, but it is not sufficient as people may require help in interpreting and acting upon the information they receive. [23]
The keyword search in the C40 Guidebook documents identified the case of Cape Town as an example in this respect. The municipality of Cape Town has recognized the challenge of using smart meter data. In addition to the installation of smart meters and the implementation of a data monitoring system, the city organized practical energy training for its facility managers. This training addressed a classic case of bounded rationality. While in theory information about energy use, load profiles etc. can be used to optimize both the technological set-up of buildings and its use; in practice a lot of background knowledge and computational skills are required. Accordingly, the focus of the training was not only on teaching the theory of energy management, but it contained a large part in which the knowledge about how to use smart meter data had to be applied in practice. [83]

5. DISCUSSION & CONCLUSIONS

The objective of this study was to critically review the nature and orientation of city-oriented climate and energy interventions in the context of behavioural economics. The working hypothesis was that virtually none of the interventions in cities explicitly address behavioural failures and that the technology policy paradigm still prevails.
An initial review of good practices for climate change mitigation at the city level shows that the focus is, indeed, on technical solutions driven by traditional policy approaches. There is little evidence for rapid decarbonization at the city level, which is driven by behavioural change policies – let alone policies explicitly addressing insights from behavioural science.

5.1. Low relevance of behavioural failures for the framing of policy interventions

The working hypothesis was not challenged by this study, which found only a low relevance of behavioural failures for the framing of policy interventions, and in contrast, a large number of traditional interventions targeting technology change. Behavioural failures are currently not dealt with in a systematic manner and there are at least three possible explanations for this (which do not preclude each other).
First, there might be a lack of knowledge/ awareness of the behavioural failures that (indirectly) affect GHG emissions and the effectiveness of policy instruments. Second, many policy interventions may already consider behavioural aspects, but they are not made explicit in the frameworks, best practice collections and case descriptions that were the basis of this study. Third, there might be widespread disbelieve that it is needed to design policy instruments to take into account behavioural failures. Indeed, since it is still very difficult to estimate the effect size of behavioural failures [71], it is important to note that non-traditional behavioural policies may contribute to decarbonisation, but they can hardly be expected to be the one and only driver of change. ‘The application of behavioural economics does not imply a paradigm shift in policymaking. It certainly does not mean giving up on conventional policy-tools such as regulation, price signals and better information.’ [84, p. 77]. To exclude interventions addressing behavioural failures altogether, would in turn run the risk of underutilising quick and low-cost policy options and designing conventional interventions less effectively than otherwise possible. Finally, results may be affected by limitations of the chosen methodological approach (see section 0).

5.2.Integrating insights about behavioural failures into the 'traditional' taxonomy

Space to introduce policy interventions that explicitly address behavioural failures is limited in the traditional way policy interventions are conceptualized. A policy taxonomy that integrates findings about behavioural failures can help to better illustrate both the opportunities and potential shortcomings of various policy interventions, and increase their salience. There are two strategies to tackle this integration. The first is to add further categories to the traditional taxonomy. This approach and was chosen to create the House of Lords taxonomy (see 4.1 and Appendix D). The second strategy is to regard behavioural failures as something to consider in the design of interventions that still may fall under the traditional categories. Sometimes behavioural failures might require small changes to existing interventions (e.g. focussing sustainable transport subsidies on people in life-changing situations); in other cases they might imply adding complementary instruments to existing interventions (e.g. training programs to a smart meter scheme); and finally they might require completely new interventions (e.g. defaults that are capitalising on loss aversion and procrastination).

Table 4: The traditional taxonomy for policy interventions - expanded by strategies to avoid behavioural failures

How to avoid behavioural failures in the intervention-driven adoption of low-carbon behaviours	**Regulation**	**Economic instruments**	**Information**	**Provision of public goods**	**Other**
Increase their salience		*life-events example*			
Make them simple to adopt					
Make them convenient to adopt					*green defaults example*
Address loss aversion					
Address hyperbolic discounting of associated costs and benefits					
Address bounded rationality			*smart meter example*		
Present them as social/ cultural norm					

A matrix as outlined in Table 4 may, thus, help to screen existing policy interventions, identify the need for complementary measures, or to develop new interventions.

5.3.Limitations and future research

This study is subject to several limitations that can be addressed in future research:

- The aggregated nature of the data that was analysed for this study did not allow comprehensive screening of all potential interventions addressing behavioural failures.
- The use of additional research methods may help to identify further examples of interventions that explicitly address behavioural failures, including interviews with municipal energy/climate change managers and in-depth case studies.
- The three examples for non-traditional interventions were merely described, but not assessed with respect to their (additional) carbon reduction potential. A structural assessment of many non-traditional interventions would be needed to argue in favour of a more widespread use of these instruments.
- The taxonomy of policy interventions addressing behavioural failures constitutes a differentiated basis for future research on bottom-up strategies of decarbonisation, including case studies, policy experiments and the development of action plans.

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APPENDIX

A. Description of urban climate networks

- *C40* is a network of megacities whose aim it is to address climate change by developing and implementing policies and programs that help to reduce GHG emissions. Established in 2006, the network connects more than 80 cities (over 600 million people, representing a quarter of the world's economy).
  Link: http://www.c40.org/
- The *Carbon Neutral Cities Alliance* was founded by 17 international cities in 2014 and is managed by the Urban Sustainability Directors Network. The collaboration aims at accelerating the uptake of good practices.
  Link: http://usdn.org/public/page/13/CNCA
- The *Compact of Mayors* is not a network as such, but provides a common platform for the collective action of cities, including the standardized measurement and reporting of emissions. Among its main goals is it to build a consistent and robust body of data on the impact of city action. The Compact was launched by the UN, the C40, ICLEI – Local Governments for Sustainability, and United Cities and Local Governments (UCLG). City actions under the Compact are reported to the *carbonn Climate Registry*, which bundles the reporting of various climate initiatives and contains more than 5000 climate actions.
  Link: http://carbonn.org/
- In Europe the *Covenant of Mayors* is by far the largest climate and energy network with more than 6000 signatories representing more than 200 million inhabitants. It was launched by the European Commission in 2008. The main instrument of the Covenant is the Sustainable Energy Action Plan (SEAP), which so far more than 5000 cities have submitted. About 1000 cities have also published monitoring reports about the progress of implementing SEAPs. The database with 'benchmarks of excellence' from the cities' SEAPs contains more than 3000 entries, which are self-reported by participating cities.
  Link: http://www.covenantofmayors.eu/
- Similarly, *Energy Cities* is the European Association of local authorities in energy transition. It was founded in 1990 and has more than 1000 cities as members. Among other activities the association offers a best practice database of nearly 500 cities' sustainable energy actions.
  Link: http://www.energy-cities.eu/

B. IPCC taxonomy for climate policies [5]

3.8.1 Economic incentives

Economic (or market) instruments include incentives that alter the conditions or behaviour of target participants and lead to a reduction in aggregate emissions. In economic policy instruments, a distinction is made between 'price' and 'quantity'. A tradeable allowance or permit system represents a quantity policy whereby the total quantity of pollution (a cap) is defined, and trading in emission rights under that cap is allowed. A price instrument requires polluters to pay a fixed price per unit of emissions (tax or charge), regardless of the quantity of emissions.

3.8.1.1 Emissions taxes and permit trading

Both the approaches described above create a price signal as an incentive to reducing emissions […], which can extend throughout the economy. […]

3.8.1.2 Subsidies

Subsidies can be used as an instrument of mitigation policy by correcting market failures in the provision of low-carbon technologies and products. They have a particular role in supporting new technologies. […]

3.8.2 Direct regulatory approaches

Prescriptive regulation involves rules that must be fulfilled by polluters who face a penalty in case of non-compliance. Examples are performance standards that specify the maximum allowable GHG emissions from particular processes or activities; technology standards that man- date specific pollution abatement technologies or production methods; and product standards that define the characteristics of potentially polluting products, including labelling of appliances in buildings, industry, and the transport sector (Freeman and Kolstad, 2006).

These regulatory approaches will tend to be more suitable in circumstances where the reach or effectiveness of market-based instruments is constrained because of institutional factors, including lack of markets in emissions intensive sectors such as energy. In 'mixed economies', where parts of the economy are based on command-and-control approaches while others rely on markets, effective climate change mitigation policy will generally require a mix of market and non-market instruments.

3.8.3 Information programmes

Reductions in GHG emissions can also be achieved by providing accurate and comprehensive information to producers and consumers on the costs and benefits of alternative options. Information instruments include governmental financing of research and public statistics, and awareness-raising campaigns on consumption and production choices (Mont and Dalhammar, 2005).

3.8.4 Government provision of public goods and services, and procurement

Government funding of public goods and services may be aimed directly at reducing GHG emissions, for example, by providing infrastructures and public transport services that use energy more efficiently; promoting R&D on innovative approaches to mitigation; and removing legal barriers (Creutzig et al., 2011).

3.8.5 Voluntary actions

Voluntary agreements can be made between governments and private parties in order to achieve environmental objectives or improve environmental performance beyond compliance with regulatory obligations. They include industry agreements, self-certification, environ- mental management systems, and self-imposed targets. The literature is ambiguous about whether any additional environmental gains are obtained through voluntary agreements (Koehler, 2007; Lyon and Max- well, 2007; Borck and Coglianese, 2009).

C. MARKET AND BEHAVIOURAL FAILURES RELATED TO ENERGY EFFICIENCY AND POTENTIAL POLICY RESPONSES [14, P. 604]

Potential market failures	**Potential policy options**
Energy market failures	
Environmental externalities	Emissions pricing (tax, cap and trade)
Average-cost electricity pricing	Real-time pricing, market pricing
Energy security	Energy taxation, strategic reserves
Capital market failures	
Liquidity constraints	Financing/loan programs
Innovation market failures	
R&D spilloversa	R&D tax credits, public funding
Learning-by-doing spillovers	Incentives for early market adoption
Information problems	
Lack of information, asymmetric information	Information programs
Principal-agent problems	Information programs
Learning by using	Information programs
Potential behavioral failures	**Potential policy options**
Prospect theory	Education, information, product standards
Bounded rationality	Education, information, product standards
Heuristic decision making	Education, information, product standards

D. Taxonomy for behavioural change interventions [72, p. 10]

	Regulation of the individual		**Fiscal measures directed at the individual**		**Non-regulatory and non-fiscal measures with relation to the individual**					
							Choice Architecture ("Nudges")			
Interventions category	*Eliminate choice*	*Restrict choice*	*Guide and enable choice*							
			Fiscal disincentives	*Fiscal incentives*	*Non-fiscal incentives and disincentives*	*Persuasion*	*Provision of information*	*Changes to physical environment*	*Changes to the default policy*	*Use of social norms and salience*
Examples of policy interventions	Prohibiting goods or services e.g. banning certain drugs	Restricting the options available to individuals e.g. outlawing smoking in public places	Fiscal policies to make behaviours more costly e.g. taxation on cigarettes or congestion charging in towns and cities	Fiscal policies to make behaviours financially beneficial e.g. tax breaks on the purchase of bicycles or paying individuals to recycle	Policies which reward or penalise certain behaviours e.g. time off work to volunteer	Persuading individuals using argument e.g. GPs persuading people to drink less, counselling services or marketing campaigns	Providing information in e.g. leaflets showing the carbon usage of household appliances **Regulation to require businesses to use front of pack nutritional labelling, or restaurants to provide calorific information on menus*	Altering the environment e.g. traffic calming measures or designing buildings with fewer lifts **Regulation to require businesses to remove confectionery from checkouts, or the restriction of advertising of unhealthy products*	Changing the default option e.g. requiring people to opt out of rather than opt in to organ donation or providing salad as the default side dish	Providing information about what others are doing e.g. information about an individual's energy usage compared to the rest of the street **Regulation to require energy companies to provide information about average usage*

*Note: * Demonstrates how regulation of businesses might be used to guide the choice of individuals, thus distinguishing it from regulation which restricts or eliminates the choice of individual.*

E. Classification of best practices “Energy Cities” [59]

Buildings
- Energy certificate/ labelling
- Energy efficient refurbishment
- New built: low energy/ NZEB/ passive

Economy & Financing
- Energy performance contracting
- European technical assistance programmes
- Incentives for local stakeholders and citizens
- Innovative financing and citizens initiatives
- Local energy funds
- Public private partnerships
- Structural and cohesion funds

Energy & climate strategy and policy
- Adaptation
- Air quality
- Building and public equipment (public lighting)
- Circular economy
- Energy production and distribution
- Fuel poverty
- Green procurement
- Heating and cooling
- Mobility and transport
- Urban agriculture
- Urban planning
- Vision/ foresight
- Waste
- Water

Local energy resources
- Biomass
- CHP/ trigeneration
- District heating and cooling
- Geothermal energy
- Hydropower
- Solar
- Waste recovery/ biogas
- Wind power

Local governance & capacity building
- Cooperation, participation, networking
- Information, education
- Local energy agency
- Training

Mobility
- Clean and energy efficient vehicles
- Public transport
- Soft mode of transport
- Traffic calming and parking
- Urban logistics

F. Classification of sustainable energy interventions “Covenant of Mayors” [85]

A	**AREA OF INTERVENTION**	B	**POLICY INSTRUMENT**
A1	**Municipal - Residential - Tertiary Buildings**	B1	**Buildings**
A11	Building envelope	B11	Awareness raising / training
A12	Renewable energy for space heating and hot water	B12	Energy management
A13	Energy efficiency in space heating and hot water	B13	Energy certification / labelling
A14	Energy efficient lighting systems	B14	Energy suppliers obligations
A15	Energy efficient electrical appliances	B15	Energy / carbon taxes
A16	Integrated action (all above)	B16	Grants and subsidies
A17	Information and Communication Technologies	B17	Third party financing. PPP
A18	Behavioural changes	B18	Public procurement
A19	Other	B19	Building standards
		B110	Land use planning regulation
		B111	Not applicable
		B112	Other
A2	**Public Lighting**	B2	**Public Lighting**
A21	Energy efficiency	B21	Energy management
A23	Integrated renewable power	B22	Energy suppliers obligations
A24	Information and Communication Technologies	B23	Third party financing. PPP
A25	Other	B24	Public procurement
		B25	Not applicable
		B26	Other
A3	**Industry**	B3	**Industry**
A31	Energy efficiency in industrial processes	B31	Awareness raising / training
A32	Energy efficiency in buildings	B32	Energy management
A33	Renewable energy	B33	Energy certification / labelling
A34	Information and Communication Technologies	B34	Energy performance standards
A35	Other	B35	Energy / carbon taxes
		B36	Grants and subsidies
		B37	Third party financing. PPP
		B38	Not applicable
		B39	Other
A4	**Municipal - Public - Private Transport**	B4	**Transport**
A41	Cleaner/efficient vehicles	B41	Awareness raising/training
A42	Electric vehicles (incl. infrastructure)	B42	Integrated ticketing and charging
A43	Modal shift to public transport	B43	Grants and subsidies
A44	Modal shift to walking & cycling	B44	Road pricing
A45	Car sharing/pooling	B45	Land use planning regulation
A46	Improvement of logistics and urban freight	B46	Transport / mobility planning regulation
A47	Road network optimisation	B47	Public procurement
A48	Mixed use development and sprawl containment	B48	Voluntary agreements with stakeholders
A49	Information and Communication Technologies	B49	Not applicable
A410	Eco-driving	B410	Other
A411	Other		

A5	**Local Electricity Production**	B5	**Local Electricity Production**
A51	Hydroelectric power	B51	Awareness raising / training
A52	Wind power	B52	Energy suppliers obligations
A53	Photovoltaics	B53	Grants and subsidies
A54	Biomass power plant	B54	Third party financing. PPP
A55	Combined Heat and Power	B55	Building standards
A56	Smart grids	B56	Land use planning
A57	Other	B57	Not applicable
		B58	Other
A6	**Local heat/cold Production**	B6	**Local heat/cold Production**
A61	Combined Heat and Power	B61	Awareness raising / training
A62	District heating/cooling plant	B62	Energy suppliers obligations
A63	District heating/cooling network (new, expansion,	B63	Grants and subsidies
A64	Other	B64	Third party financing. PPP
		B65	Building standards
		B66	Land use planning regulation
		B67	Not applicable
		B68	Other
A7	**Other**	B7	**Other**
A71	Urban regeneration	B71	Awareness raising / training
A72	Waste & wastewater management	B72	Land use planning
A73	Tree planting in urban areas	B73	Not applicable
A74	Agriculture and forestry related	B74	Other
A75	Other		