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Demand side climate change mitigation actions and SDGs: literature review with systematic evidence search

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Demand side climate change mitigation actions and SDGs:
literature review with systematic evidence search

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**Keywords:** SDG, industry, transport, buildings, avoid-shift-improve, actor, mitigation actionsSupplementary material for this article is available [online](#)**Abstract**

To strengthen current discourse on acceleration and scale up of the emissions mitigation actions by sector-specific demand side actions, information on the intersection of three dimensions becomes useful. First, what kind of actions help in avoiding, shifting and improving demand for activities/services and resultant emissions to help in deciding choices for actions; second, how these three categories of actions are linked to the wider impact on human wellbeing represented by the Sustainable Development Goals (SDGs) framework; and third, who are the actors associated with these mitigation actions. These three steps become important in the targeted scaling up of actions through policy interventions. This study undertakes a review of the literature between 2015 and 2020 with systematic evidence searching and screening. The literature search has been conducted in Scopus Database. From over 6887 literature in the initial search, 294 relevant literature were finally reviewed to link demand side interventions of avoid-shift-improve (ASI) categories to SDGs. It also maps these actions to actors who can lead the changes. Results show that a wide range of improvement actions are already helping in incremental steps to reduce demand and emissions in various services like mobility, shelter and industrial products. However, ASI categories provide more distinct mitigation actions. All actions need support of innovation, infrastructure development and industrialization. Actions that interact with several SDGs include active mode of transport, passive building design, cleaner cooking, and circular economy. Positive links of these actions to multiple SDGs are overall very strong; however, few trade-offs have been observed. These are mostly related to distributional impact across social groups which highlight the need for policy attention and hard infrastructure design changes. Mitigation and wider benefit outcomes cannot be achieved by individual or household level actions alone. They require the involvement of multiple actors, interconnected actions in sequence as well as in parallel, and support of hard infrastructure. Our results show that in mobility services, policy makers supported by spatial planners and service delivery providers are the major actors. In industry, major actors are policy makers followed by spatial planners and innovators. For buildings, key actors include spatial planners followed by policy makers. Besides these, strategic information sharing to enhance user awareness and education plays an important role in shaping behaviour. Digitalization, information and communication, and interactive technologies will play a significant role in understanding and modifying people's choices; however, these would also require regulatory attention.

1. Background

Acceleration in mitigation actions from now through the next two decades simultaneously by all countries and across all sectors is emerging as an imperative from all global assessments (IPBES 2016, UNDP 2016, UNEP 2017, IPCC 2018, 2019, EAT-Lancet Commission 2019, HIMAP 2019) to avoid catastrophic consequences and to avoid very high and many uncertain mitigation costs associated with uncertain technologies. One strong argument in favour of wide scale global participation in climate mitigation action comes from the scientific community who are highlighting clear wider developmental co-benefits from climate mitigation (Dubash et al 2013, Bajželj et al 2014, Behnassi et al 2014, Campbell et al 2014, Lipper et al 2014, Long et al 2016, Creutzig et al 2018, Ürge-Vorsatz et al 2018, Roy et al 2018a). Development and employment literature (Elasha 2010) see near term national developmental priorities including energy security concerns as urgent priorities and mitigation action as a long-term goal. Sustainable development goals (SDGs) provide a common overarching framing for development that addresses both long-term sustainability and wider human wellbeing oriented developmental goals in the near future for all countries. Climate action is the 13th goal under 17 politically negotiated globally accepted SDGs. Mitigation is one of the climate actions proposed under SDG 13. Synergy and trade-off between mitigation action and the SDGs are now well acknowledged in the literature (Roy et al 2018a, Hoegh-Guldberg et al 2019, Some 2020). An IPCC special report on the 'Global Warming' of 1.5 °C assessed extensive literature to report the indicative linkages between climate action within the SDG framework (Roy et al 2018a) without going into an assessment of net positive and negative impacts. Users of the report expressed its usefulness and a desire for additional assessment of net wider impact. The caption to Table SPM 4 in the IPCC SR1.5 notes the need for further assessment. The IPCC SR1.5 also identifies the lack of adequate studies that address interlinkages between climate mitigation and adaptation and resilient socio-economic transformations.

Our goal in this article is to pick up from the more conclusive findings in the SR1.5, which highlights that demand side mitigation actions are more synergistic with SDGs compared to supply side actions and conduct a deeper investigation using systematic evidence search and screening of the existing literature for a better understanding of the evidence on SDG impacts of demand side mitigation actions grouped under avoid-shift-improve (ASI) categories, and further into actors who can lead the actions.

The ASI categories we borrow from applications in the 1990s in the transport sector. Recently Gota et al (2019) reviewed up to 1500 low-carbon measures in 81 countries, which are grouped under the 'avoid'

category as those aiming to decrease the need for transport trips, 'shift' representing actions that enable a shift to substitute modes for service provision, and 'improve' represents actions aiming to look for more efficient appliances. Given the simplicity of the ASI categorisation, recently there is an increasing focus on applying the ASI category beyond the transport sector (Creutzig et al 2018). Given this background, this study undertakes to prepare a review by a systematic evidence search and screening to address the overarching research question, 'what evidence exists on various mitigation actions implemented in various regions that can be categorized under *avoid*, *shift* and *improve* in demand for products and services, how do they interact with SDGs, and who are the main actors who drive mitigation actions?' The study considers the interaction of mitigation actions with all 16 non-climatic SDGs. Three energy demand sectors (services) chosen are: transport (mobility), industry (variety of products) and building (shelter and commerce).

2. Method

We have followed a systematic evidence search and screening of literature and evidence. It is performed by using relevant keywords within the scope of the research question to find out all the relevant literature within the Scopus database. Being systematic helps us in removing bias of selecting and omitting literature (Lamb et al 2018).

It is very basic, but due to its elegance we organize and segregate the research question in population-intervention-outcome (PIO) elements. The PIO elements of the research question are:

Population(s): energy end use sectors (industry, transport and building) mapped into goods and service typologies e.g. industrial manufactured goods such as clothing for thermal comfort, transport for mobility and buildings for shelter for commercial and institutional functions for homes, hospitals, schools and workspace. However, we use sectors and services interchangeably in the article.

Intervention(s): a range of mitigation actions relating to various sectors mentioned in the *population* above. These mitigation actions are categorized as changes at technical, behavioural and infrastructural and/or systemic level.

Outcome(s): synergies and trade-offs with all 16 SDGs with goal 13 (climate action) as climate mitigation actions in energy demand sectors are the entry point of this study.

2.1. Literature search

To identify demand side mitigation actions for end-use sectors such as transport, industry and building, search queries (annex A) are developed on the sector-specific key elements PIO (population (Query 1), intervention (Query 2) and outcome

(Query 3)) of the research question. We divide outcome-related search terms into two parts: Query 3a and Query 3b; the first one focuses on various demand side actions for mitigation and the second one is to constrain results to those relevant to SDG linkages. The search was performed in Scopus. We are aware that these same search strings would have fetched different results in other databases (Bramer et al 2017) but we have used only Scopus because it is more user-friendly in terms of downloading search results directly in .csv format than other databases like Web of Science (Core Collection). We have limited the study period between 2015 and 2020 to align with the SDGs and for the ongoing IPCC Sixth Assessment Cycle (AR6). Annex A provides a list of search terms used for the three sectors.

2.2. Screening

Articles from the above search were considered for inclusion in three successive levels following selected inclusion criteria (annex B). The first step was title screening followed by abstract screening and finally full text review. In case of uncertainty during the title or abstract screening, the article was included by default in the next step of screening. After the abstract screening, 12 articles randomly selected from each sector were checked by all the four authors for consistency and agreement between the authors and were recorded using the Kappa test. The Kappa values are ranged in between 0.63 and 0.71 ($k = 0.71$ for transport: SS vs JR; $k = 0.63$ for industry: ND vs JR; $k = 0.66$ for building: MP vs JR).⁵ The scores indicate moderate agreement.

The final step was a full text review of short-listed articles for inclusion in the final analysis. The articles were distributed by sector among two reviewers: transport-JR and SS, industry-JR and ND and building-JR and MP. General inclusion and exclusion criteria were set *a priori* for all the three sectors at the different stages of screening (annex B).

2.3. Data/information extraction

Articles included for final analysis are thoroughly reviewed. We used a detailed coding sheet (see the supplementary file which is available online at stacks.iop.org/ERL/16/043003/mmedia) to record the mitigation actions, the country context, the SDG linkages and the actors along with all other necessary information related to the articles like the title of the article, publication year, source and the DOI.

2.4. Synthesizing data/information

We grouped various demand side actions from the supplementary file into the ASI category following Creutzig et al (2018). The ASI category for all three end-use sectors in this paper is grouped as

follows. The *Avoid* category includes actions aimed at avoiding the demand for high-emission intensive services (mobility, manufactured product, shelter and building services including cooking); actions in the *shift* category help in substituting demand for high-emission intensive services with low/no intensive ones; and *improve* category actions are aimed at improving the energy/emission intensity of a service type. Two reviewers from each sector categorized the interventions into the ASI category and in case of ambiguity, a third reviewer was consulted to solve the discrepancies. We then mapped the SDGs' impacts of individual ASI interventions (see supplementary file). SDGs are interlinked, so trying to achieve one goal (here SDG 13) have wider impacts (synergies and trade-offs) on other goals (other 16 SDGs, except SDG 13). Therefore, it is important from a policy perspective to understand these wider impacts that the demand side mitigation actions imply. We have mapped the wider impacts from the implementation of demand side mitigation actions (SDG 13) against the other SDGs, for each of the three end-use sectors (see table 1, figures 3–5 and supplementary file). Then, we tried to see which actors can be associated with these mitigation actions. This becomes important in targeted scaling up of actions through policy interventions. These findings are presented in section 3.

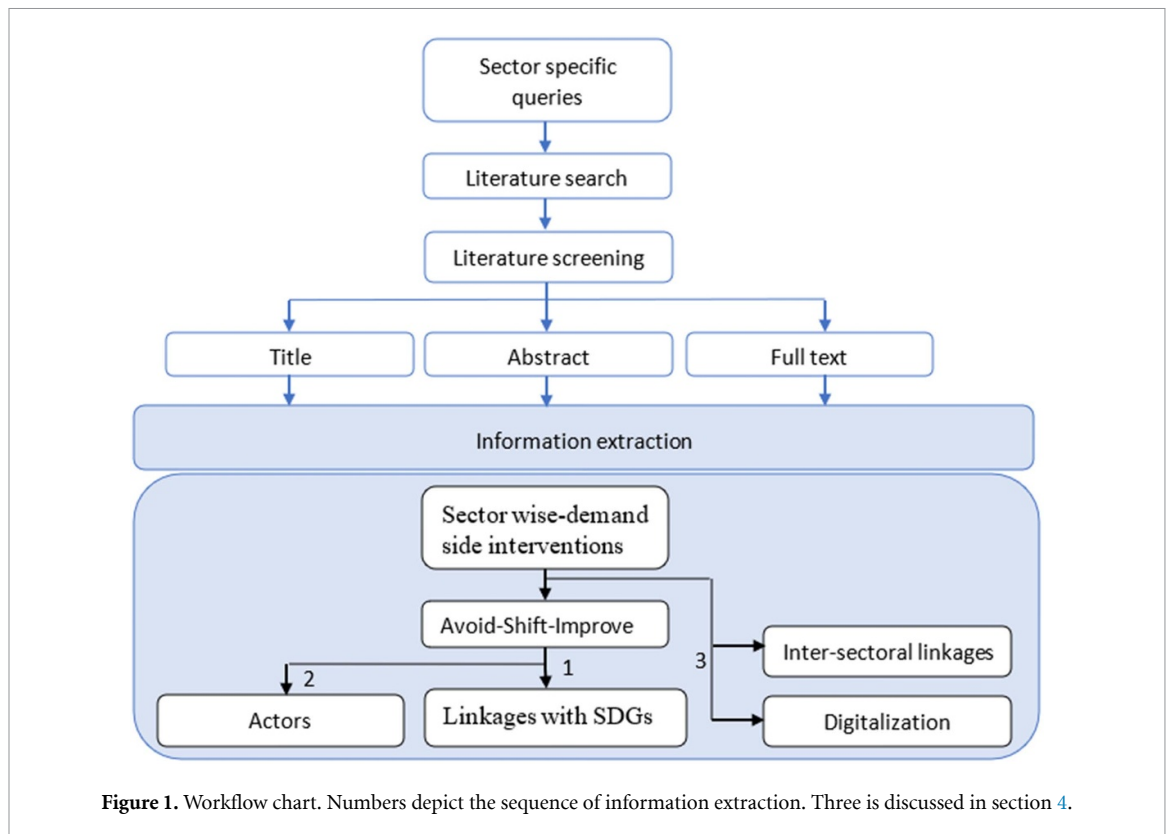
While reviewing the articles, we found interesting inter-sectoral linkages that can aid in taking the mitigation actions. We report the findings of the inter-sectoral linkages and digitalization in section 4. Figure 1 presents the workflow chart.

3. Results

3.1. Descriptive statistics

The search queries fetched a total of 6887 studies. Annex C provides details of the articles included after each screening stage. Below we describe the screening stages for each sector. A total of 294 articles are included for detailed analysis. Studies included in the review spanned a wide geographic scope representing over 67 countries with a large number of studies from Europe, Asia and North America (figure 2). Considering all the sectors, most studied countries are China ($n = 25$) followed by USA ($n = 21$), UK ($n = 17$) and India ($n = 15$). In total, 18 studies had a wider scope focusing either at the global level, on a specific region or on developing countries in general. For the transport sector, most studied countries are China ($n = 10$), followed by USA ($n = 9$) and India ($n = 8$). Out of 107 transport sector studies included in the review, 50 are developed country studies while 47 are developing country studies. For the industry sector, the most studied countries are China ($n = 6$), followed by India and Italy ($n = 2$). Out of 59 studies for industry included in the review, 7 are developed

⁵ JR: Joyashree Roy, SS: Shreya Some, ND: Nandini Das, MP: Minal Pathak



country studies while 11 are developing country studies. For building sector, most studied countries are USA ($n = 12$), followed by China ($n = 9$). Of the 128 studies included in the review or building sector, 95 are developed country studies while only 19 are developing country studies.

3.2. Transport

In this sector, we have grouped mitigation actions in service delivery into the ASI category (see annex D) following Creutzig *et al* (2018). The *Avoid* category includes actions aimed at avoiding the demand for mobility services: compact urban planning which helps in avoiding mobility and reducing vehicle ownership. *Shift* category actions help in substituting demand for mobility services with a low/no emission intensive one: increasing the use of active travel and more use of public transport. While, actions in the *Improve* category are aimed at improving the energy/emission intensity of a mobility service type: shared mobility, use of electric vehicles (EVs)/zero emission vehicles, hydrogen buses, etc.

3.2.1. ASI-SDG link

Mitigation actions in the mobility service sector deliver multiple benefits and therefore show synergies with several SDGs (table 1). Compact urban planning and reducing vehicle ownership cater to sustainable cities and reduce air pollution (SDG 11). Active mobility requires the development and strengthening of partnerships (SDG 17) for planning (Macmillan

et al 2020) the infrastructure. Shifting to active modes such as walking, cycling, etc, reduces mortality and provides health benefits (SDG 3) but has a collision risk if not supported by separate lanes (Doorley *et al* 2015). Using active modes (cycling) generates income for the local communities (SDG 1 and 8) and for commuters, these are very low-cost methods for accessing basic services (Macmillan *et al* 2020) for developing countries. Active modes can reduce gender inequities in access to basic services, healthcare and education (SDG 5). Education and awareness programs aid in understanding the environmental benefits of shifting to public transport and e-vehicles (Bigerna *et al* 2019). Urban environments that enable active travel modes for trips have the potential to reduce physical and financial barriers to participating in education for women thereby catering to SDG 5 (Macmillan *et al* 2020). A study in Canada (Mitra and Nash 2019) has shown that providing a bike lane facility improves the chances of females (SDG 5 and 10) commuting by bike. The use of public transit and active modes demands proper infrastructure (SDG 9) and saves energy (SDG 7). Also, Sjöman *et al* (2020) mentioned that transit-oriented infrastructure (SDG 9) helps in avoiding ownership of private vehicles. However, in some developing countries weather conditions and unreliable connectivity affect the lack of incentives to improve existent infrastructure related to public transportation (Bonasif 2017) and active modes. Gilderbloom *et al* (2016) pointed out that shifting to active modes and reducing car demand preserves land (SDG 15) that would have been otherwise used to

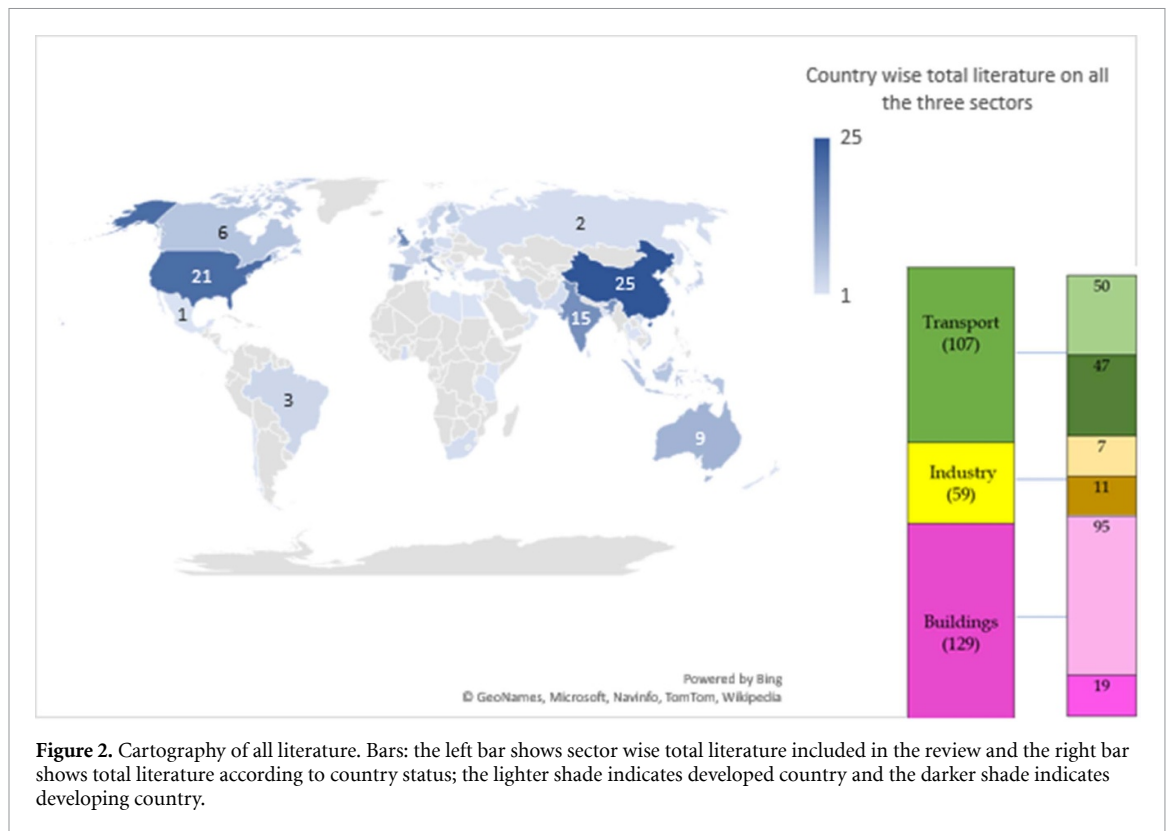


Figure 2. Cartography of all literature. Bars: the left bar shows sector wise total literature included in the review and the right bar shows total literature according to country status; the lighter shade indicates developed country and the darker shade indicates developing country.

construct and maintain parking garages and surface parking lots.

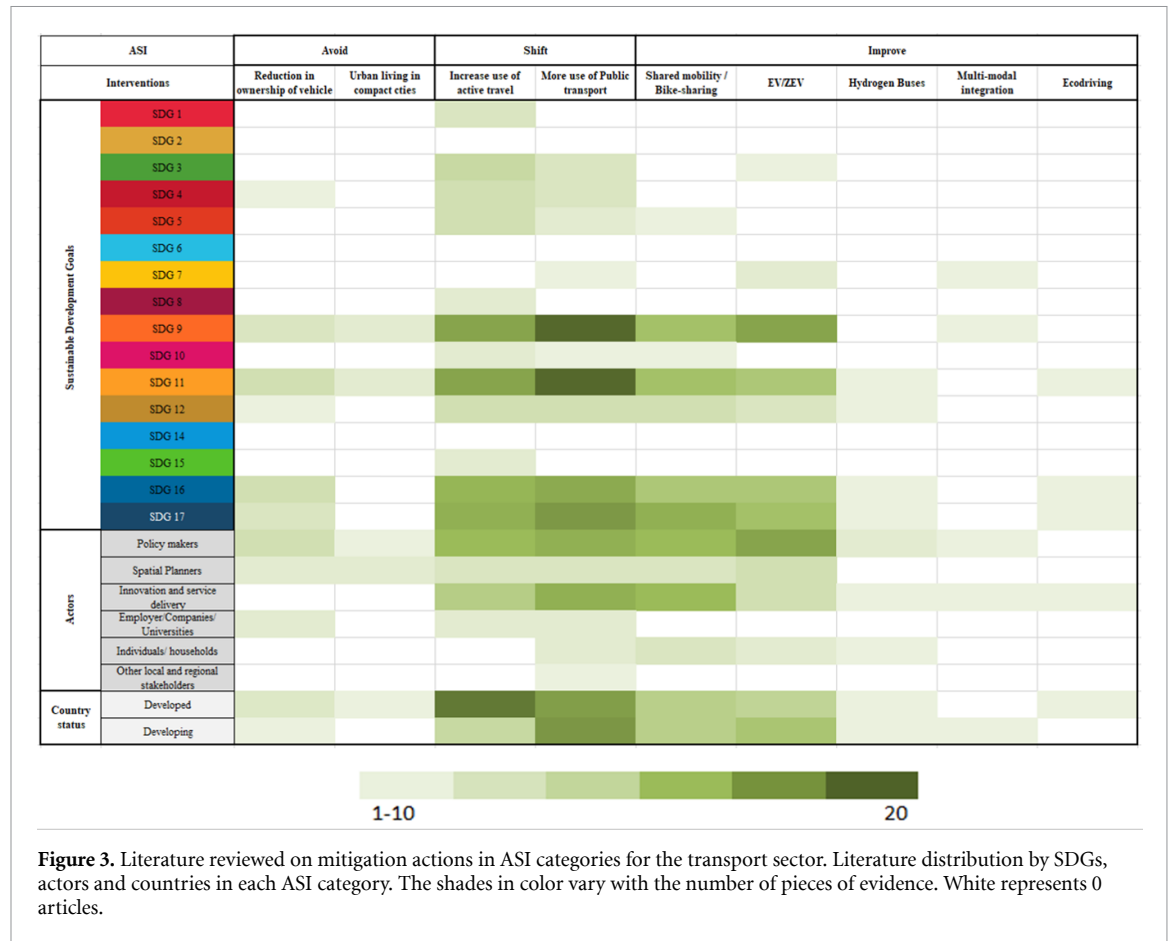
Improving service efficiency (e.g. car sharing) or fuel switch (e.g. hydrogen buses; EVs) (Creutzig *et al* 2018) helps improving mobility service demand with relatively less emission. Sharing mobility services has come a long way now but commuters with a private interest in driving their own car need to understand the importance of sustainable consumption (SDG 12) and act altruistically (Mehdizadeh *et al* 2019). Using low or no-carbon fuel and efficient car help in reducing air pollution which provides direct health benefits (SDG 3) (Yang *et al* 2018). Also, studies have shown that digitalization has helped women to use more carpooling due to the built-in safety features (SDG 5, 10 and 11). However, subsidizing EVs for greater adoption may lead to higher sales among active travelers (Rudolph 2016, Zhang *et al* 2018).

Out of 107 selected studies in the final analysis, almost all studies point toward benefits across the various dimensions of sustainable development from mitigation actions for transport. Overall, no direct linkage has been found with SDGs 2, 6 and 14. Most of the linkages are with SDGs 9 and 11, clearly showing the relevance of innovation and infrastructure for sustainable transportation, followed by SDGs 16 and 17, clearly depicting the crucial role of actors like government and planners in ASI. It is apparent from figure 3 that actions in the shift category and a few in the improve category (shared mobility and EVs) have more evidence for the SDGs link.

3.2.2. Actors and examples of mitigation actions

Spatial planners and policymakers are identified as the major actors for helping in avoiding the demand for mobility services. There are various examples where imposing high congestion charges for driving in the central parts of the city like in London (Ahmad and Puppim de Oliveira 2016), rewarding the (voluntary) forfeit of a (second) car in the household (Schoenau and Müller 2017), and imposing high parking fees and high taxes on cars (Ahmad and Puppim de Oliveira 2016) by local governing bodies may have helped reduce ownership of a vehicle. Imposing high parking fees is supported by both developed (Langlois *et al* 2015) and developing (Becker and Carmi 2019) countries. Spatial planners (e.g. urban planners and designers) (Stojanovski 2019) can adopt long-term strategies like increasing housing supply near the workplace (Schneider and Willman 2019) or transit stops (Langlois *et al* 2015) to avoid mobility demand. The Seoul Smart Work Center is an initiative for all government employees to work closer to their homes. In 2015, 30% of the employees were covered under this scheme (Shmelev and Shmeleva 2018).

Indian mega cities such as Mumbai and Kolkata have historical advantages of a well spread-out infrastructure of public transport. Kolkata, Pune and Delhi's comprehensive mobility plans and master plans have set a target of achieving 90% modal share in the form of public transport (Roy *et al* 2018b). The involvement of actors at multiple levels



is necessary to shift mobility demand from private mode to public modes. For example, spatial planners (e.g. road planners) or policymakers can adopt various actions like reduced road space for cars; introduce programs like ‘car free Sundays’ in the city center as done in Bristol; and communicate the environmental benefits of using sustainable transport (Mir *et al* 2016), while service delivery agents can improve the quality and frequency of service (Trinh and Linh 2018). Developed country studies suggest innovative design for bus services considering user needs at the bus stop (Hildén *et al* 2016, Mozos-Blanco *et al* 2018) while developing country studies point out that public transport may not a preferable option due to poor schedule, dirty stations (Lelono *et al* 2018) and also poor-quality service like rude staff, low-quality buses, crowding (Trinh and Linh 2018), less safety and careless bus drivers. Therefore, innovation and service delivery through service delivery agents have different roles in developed (innovative service design, digitalized mobility (Sjöman *et al* 2020)) and developing countries (professional training to bus drivers and ticket collectors, providing bus route information, timetable (Trinh and Linh 2018)) to boost demand for public transport. Shifts toward the public transport system in India are backed by policy and practice, as well as an investment model through well-defined private

sector participation along with the introduction of joint strategies for energy efficiency of equipment and a switch to electrification (Roy *et al* 2018b). However, in developing countries like Ghana and India, people with higher education use less active transport, as owning a car indicates higher social status (Acheampong and Siiba 2018); therefore, individuals’ own lifestyle choices are also important in making mobility service decisions.

The roles of universities, educational institutes and companies are important both in raising awareness and helping to changing the behavior of individuals. For example, companies can provide monthly prepaid public transport passes rather than private transport allowances (Ahmad and Puppim de Oliveira 2016) as done in Seoul and Tokyo which encourage staff to commute by public transport. To promote active travel, policymakers and local stakeholders should advocate the environmental benefits of walking and cycling/biking (Ho *et al* 2017, Schneider and Willman 2019). Policymakers and spatial planners like road planners should provide better infrastructure and provide a user-friendly environment to encourage people to walk and bike for their non-work travel needs (Ramezani *et al* 2018, Carroll *et al* 2019, Useche *et al* 2019). While actors like companies (corporate offices) can motivate their employees to use active travel like in Boston, USA, 14

companies are motivating employees to commute to work using bikes (Wunsch *et al* 2016). There are several case-studies (Aittasalo *et al* 2017, Fenton 2017) on promoting active modes available for developed countries. Already in many developed countries like Canada and the USA, actions from policymakers and public investment in infrastructure have helped in upscaling active modes (Ramezani *et al* 2018, Mitra and Nash 2019). Interesting to note here that there are very limited studies (figure 3) that discuss promoting active travel in developing countries. These studies (Wethyavivorn and Sukwattanakorn 2019) suggest scaling up active modes for solving last mile problems.

Multiple actors have roles to play in improving mobility service demand. In most of the metropolitan cities in both developed and developing countries, Uber/Ola/Lyft/similar service providers are extremely common. These actors have introduced a vehicle pool service facility where commuters traveling in the same direction can share rides and save money. Policymakers can also promote shared rides through policies (Ceccato and Diana 2018). Sharing mobility services for children's school travel is the responsibility of the parents as household actors (Mehdizadeh *et al* 2019). In Indian cities like Kolkata, school-bus and carpools are the most common means for transportation of school children but the parents of school children have shown concern about poor service quality, safety, staff behavior, journey time and waiting time (Prasad and Maitra 2019). Most schools prefer a school bus to car pools due to safety issues (South Point School 2019). Actors like employers are providing car sharing platforms for their staff. Therefore, service delivery agents need to look into safety issues to scale up shared ride among school students. Policymakers (e.g. national or local government) support in terms of financial aid (subsidies), infrastructure (charging stations, proper roads) and training facilities for the drivers are very crucial in upscaling EVs (Zhang *et al* 2018, Ahmed and Karmaker 2019, Tu and Yang 2019) in both developed and developing countries. In countries like South Korea and Chile, the government provides subsidies for the adoption of electric taxis (Aymeric and François 2017, Kim *et al* 2017). However, to date low penetration of EVs has been a problem, but the reality is changing very fast. The reasons for low penetration are high battery cost and low availability of charging points. In Chile, as of 2014, only 136 vehicles (0.003% of the total fleet) are electricity-fuelled (Aymeric and François 2017). It is also important for innovation and service delivery providers to provide adequate charging points to support the penetration of EVs. In Brazil, the Itaipu hydroelectric power plant has established an electric-car sharing platform for its employees (Vanzella *et al* 2018). Households/individuals can play their role by paying a higher price for low polluting travel. A study (Bigerna and Polinori 2015)

designed to find the willingness to pay for hydrogen buses in Perugia, Italy reveals that commuters are willing to pay 30%–60% more than the single-trip bus fare.

3.3. Industry

Demand reduction for industrial products can happen at two stages, intermediate demand for the products used as input in other manufacturing processes and final demand from the end-user. However, it is identified to happen mostly outside the industry sector (Fischedick *et al* 2014). We identified 14 mitigation actions following a full-text screening of 39 articles. These actions for the industry sector are presented in annex E. These actions are broadly grouped into three categories, *avoid* demand/consumption of virgin materials and inputs by using more recycled and by-products, reduced emission intensity by *shifting* to the low-carbon or renewable energy sources and modern manufacturing process and *improved* material efficiency and energy efficiency. The most commonly studied intervention is clustering of the industries through an eco-industrial park (EIP) and industrial symbiosis (IS) (Jin *et al* 2017, Guo *et al* 2018, Fraccascia 2019, Huang *et al* 2019). In IS when a group of firms located in the same area and interconnected to share water, energy and by-products, the operating efficiency of individual firms improves (Bellantuono *et al* 2017). The symbiotic relationship among firms in EIP and IS avoids material use and facilitates the use of by-products and waste recycling (ElMassah 2018), thereby reducing the consumption of materials and energy and consequent reduction of GHG emissions. Two important demand side mitigation actions in industry are reducing emission intensity and improving energy efficiency at the production process level. From the final analysis of the selected literature, nine actions refer to improvement of technological efficiency with deployment of clean and green technology (Ashraf *et al* 2018, Guo *et al* 2018, Hens *et al* 2018, Bertarelli and Lodi 2019, Safarzadeh and Rasti-Barzoki 2019) smart energy system, recovery of waste heat (Zhang *et al* 2016), energy management system (Javied *et al* 2015).

3.3.1. ASI-SDG link

Based on the literature review the demand side mitigation actions for the industry sector are mapped against eight SDGs. From the selected literature goal numbers 1, 2, 4, 5, 10, 14, 15, 16 could not be linked directly. Out of 59 selected studies for final analysis only 12 studies have established direct linkages between SDGs and demand side mitigation actions for the industry. The remaining studies, while do not mention SDGs specifically, point toward benefits across the various dimensions of sustainable development. Goal number 9 directly addresses sustainable industrialization by fostering innovation. In

our selected studies almost all the 14 actions are contributing to achieving this goal (Bertarelli and Lodi 2019) mainly through technological innovation (Pigosso *et al* 2018) and improved energy and emission efficiency (Wang *et al* 2018b). Sustainable production (SDG 12) with efficient resource management, an important impact of demand side actions with material efficiency (Abreu *et al* 2017, Bai *et al* 2018), use of by-products in a symbiotic production system (Bellantuono *et al* 2017) and circular economy (Yang *et al* 2019). We have been able to link a total of 8 actions with SDG 12. Cooperation and communication among firms and financial stability with a suitable business model seem to be the most important aspects of clustering of the industries (Menato *et al* 2017). This also helps attain SDG 17 which addresses partnership to achieve sustainable development through domestic cooperation (see table 1, figure 4 and supplementary file).

It is apparent from figure 4 that *avoid* category actions have the strongest connection with the SDGs. If we analyze these interventions in the context of developed and developing countries, we can see that *avoid* category actions like IS and EIP are important demand side mitigation actions for both developed and developing countries. However, the importance of *avoid* (circular economy), *shift* (use of low carbon energy sources) and *improve* (technological efficiency) has a larger importance in developing countries. Smart energy management and smart energy systems have less relevance in developing countries (figure 4).

3.3.2. Actors and examples of mitigation actions

Industrial symbiosis and EIP has emerged as one of the important action from the demand side both in developed and developing countries. However, the driving force of IS is cooperation among industries operating in IS/EIP, information sharing (ElMassah 2018) and shared support services (Fraccascia 2019) which are influenced by various technical, economic, and legal factors (Huang *et al* 2019). The heterogeneity of the existing firms in a cluster is key for a successful aggregation (Bellantuono *et al* 2017). At the organizational level the roles of spatial planners such as operators of the firms, IS facilitators, and policymakers become crucial to facilitate a convenient sharing platform for the implementation of a stable IS (Bellantuono *et al* 2017, Fraccascia 2019). In order to extend the possible use of by-products and for better energy management, linkages with research organizations are important (Guo *et al* 2018). Among these studies, two studies have argued that tax deduction instead of subsidy can be a more effective instrument to encourage the use of energy-efficient and clean technology (Pillay and Buys 2016, Bertarelli and Lodi 2019), which has also been supported by theoretical models for a long time (Pearce and Turner 1990). In this case the role of a regulatory mechanism

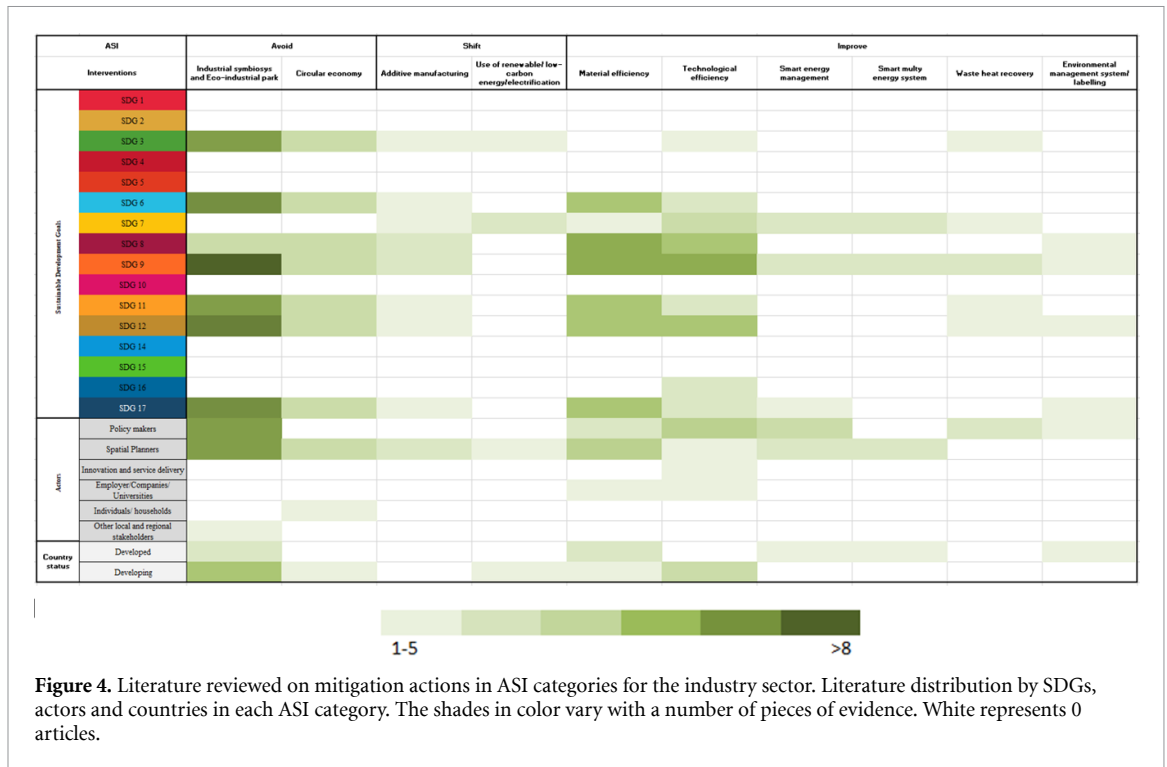
to strengthen the market instruments and optimum policy defining the role of policymakers such as government is crucial.

At the user end, actors involved in innovation and service delivery facilitate through digitalization to create an alternative form of provisioning system, say e.g. for clothes swapping through various on-line applications (apps) and also creating pop-up marketplaces (Holmes 2018). Dedicated websites for clothes swapping like 'swishing.co.uk', 'swopped.co.uk' or apps like 'This for That' have provided new marketplaces for used items of clothing (Holmes 2018) and also contribute to avoiding the demand for new clothing and hence textile industry products. The use of digital media in daily activities like switching to an electronic newspaper is reducing demand for paper newspapers (Permatasari *et al* 2018).

3.4. Buildings

While the ASI category has been extensively applied to the transport sector, very few studies have discussed this for the building sector (Creutzig *et al* 2018). Demand reduction from the building sector includes actions that avoid the need for floor area/building footprint or those which reduce the energy consumption for space heating/cooling, illumination from lighting, cooking and use of various energy using appliances. Actions that reduce the need for energy intensive materials for building construction such as cement could include substitution or use of alternate materials such as fly ash, wood, bamboo or other local materials. For the purpose of this study, these actions are excluded. We focus only on the emissions from building operations or services. The *avoid* category refers to actions that reduce the need for heating or cooling such as passive construction including the use of daylighting, shading, building form and orientation and use of natural ventilation (annex F). Given that many of the green building mitigation actions such as passive design, cool roofs, and green roofs avoid the demand for artificial lighting, heating or cooling services, we include green buildings in the avoid category.

The *shift* category includes actions such as switching to more alternative substitutes, cleaner cooking fuels and technologies and district heating or cooling. Shift to cleaner cooking fuels is a significant shift action contributing to substantial energy efficiency improvements and SDG benefits discussed in the subsequent section. Purchase or replacement of efficient appliances that fall into the *improve* category (annex F) are shown to deliver substantial energy savings; however, some studies in Japan, China and Taiwan reported rebound effects undermining total potential energy savings (Mizobuchi and Takeuchi 2016, Su 2019). Environmentally sustainable design including the use of daylight, management of circulation area could significantly reduce the need for heating/cooling and artificial lighting (Lourenço *et al*



2019). Several studies reported the use of information and communication technology (ICT), Internet of things (IoT) devices that provide real-time consumption data provided useful information to households stimulating energy saving behavior. Such automated systems achieve significantly higher results when matched with conscious and sustainable consumers (Fabi *et al* 2017). Behavioral aspects could have significant impacts on energy consumption and need to be accounted for (Walzberg *et al* 2019), which makes it necessary for decarbonizing strategies to go beyond a technology centric approach and include social dimensions (Sodagar and Starkey 2016).

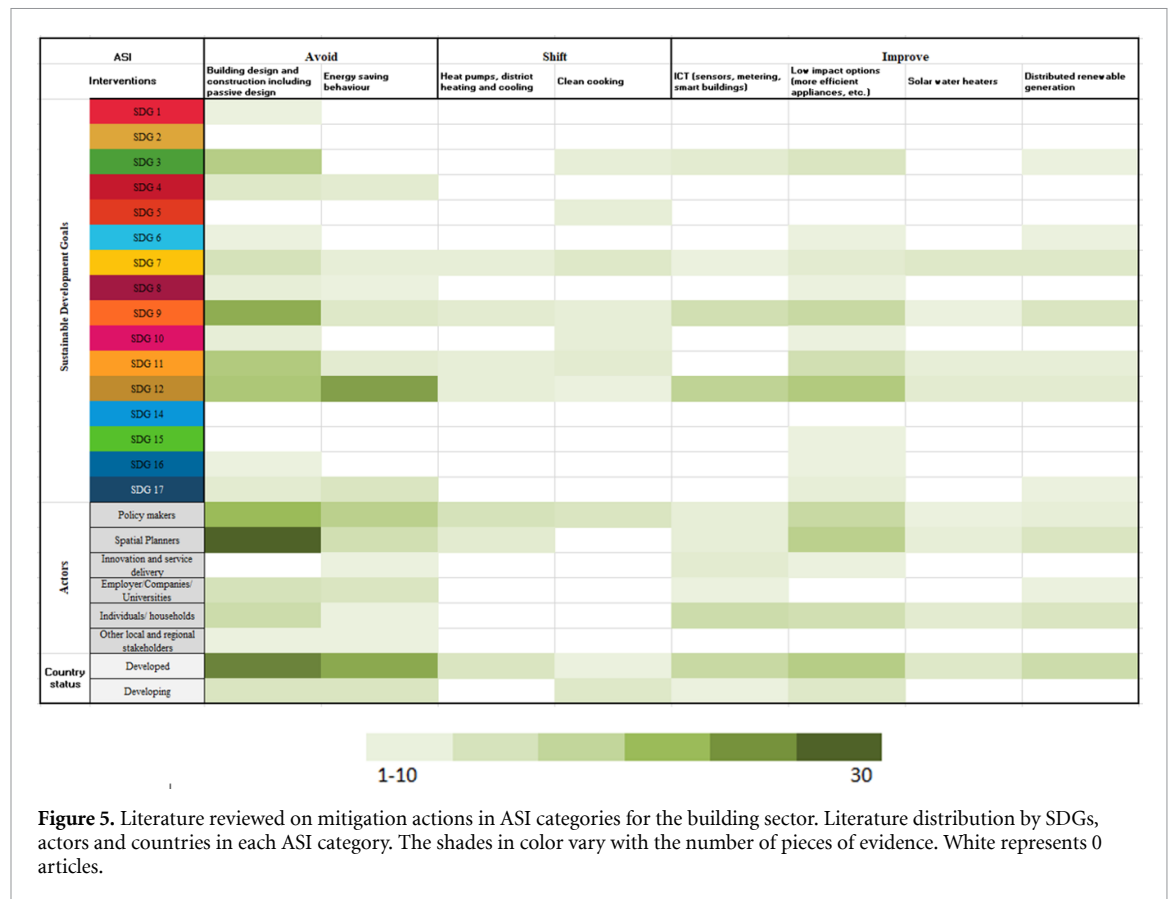
Studies on passive building design, energy saving behaviour and efficient appliances were found for both developed and developing countries however, not surprisingly, there were more studies for developed countries compared to developing countries. Studies on heat pumps, ICT and renewable energy/distributed generation were found mostly for developed countries indicating a higher level of technology penetration.

3.4.1. ASI-SDG links

Demand side actions for buildings deliver multiple benefits and therefore show synergies with several SDGs (table 1). However, there are stronger synergies with SDGs 3, 7, 9, 11 and 12. The highest synergies are observed with SDGs 7 and 9 (figure 5). Sustainable buildings through their numerous mitigation actions such as passive design measures, green and cool roofs, greening systems, water efficiency and other actions enhancing thermal comfort, and

financial benefits have the opportunity to deliver multiple positive impacts especially enhancing the health and wellbeing of occupants and therefore we see positive interaction with SDG 3 (Balaban and de Oliveira 2017, Alawneh *et al* 2018). Sustainably built infrastructure is central to sustainable communities and cities (SDG 11) and buildings, especially large institutional buildings contribute to resilient communities and cities. Studies highlight the need to interpret these benefits with caution as in some cases, certified green buildings or green products could lead to more adverse indoor air quality and health hazards (Steinemann *et al* 2017). Some studies also show that the performance of green buildings could decline over time undermining the initial benefits (Zaid *et al* 2017) highlighting the need to undertake long term green building performance evaluations.

Building services are essential for wellbeing and therefore these have a strong impact on equity. Elements include thermal comfort, adequate lighting, heating and cooling and other services. The use of informal biomass for cooking remains a persistent issue globally despite advances in the energy sector and therefore enhanced access to clean cooking fuels and stoves can contribute significantly to overall wellbeing (Poblete-Cazenave and Pachauri 2018). Such a transition could contribute to achieving SDG 7 on universal clean energy access, but also improve gender equality (SDG 6), and health outcomes (SDG 3) (Rosenthal *et al* 2018, Batchelor *et al* 2019). Improved illumination and indoor air quality in schools can improve student’s learning outcomes and provide opportunities for energy



savings (Hu 2017, Lourenço et al 2019), for low income housing, this could also improve women and child health (Rosenthal et al 2018). Similarly, meeting the demand with renewable energy resources caters to SDG 7 on energy security. Technology-led or behavior-led mitigation actions that promote production and use of efficient devices further targets SDG 12 (Withanage et al 2016). Research in energy systems, smart-grids, smart-meters and other technology combinations spur green innovations contributing positively to SDG 9. While efficient appliances have been discussed in most studies, few papers discuss the adequate levels of appliance ownership to ensure decent living standards for societies. A large share of the population in developing countries lacks access to air conditioning and cooling devices. This could further exacerbate energy poverty adversely impacting SDGs 3 and 7 (Mastrucci et al 2019).

3.4.2. Actors and examples of mitigation actions

A number of actors influence the building sector ranging from policymakers (government and quasi-government agencies) to a number of spatial planners (private stakeholders like real estate developers, builders, architects, designers), local stakeholders (like regulatory agencies) and households. Figure 5 shows the various building related mitigation actions

and the actors that can influence change. Policy-makers at all levels can influence and support the adoption and upscaling of building interventions. At the national and state level, these include building codes and policies, appliance standards and efficiency targets. National building codes have been successful in most implementing countries. At the local level, planning authorities, independent architects and building professionals exert significant influence on local regulations and targets including building design guidelines and overall urban built form. Accelerated adoption of green building standards also depends on an enabling market environment (Teng et al 2019). Rating agencies or government departments could facilitate green buildings or related sustainable mitigation actions by setting effective standards (Darko et al 2017), through supportive policies technical support and financial assistance (Balaban and de Oliveira 2017), by working with service delivery actors like industry stakeholders to remove regulatory bottlenecks. The private sector also exerts significant influence as a supplier of building services. This includes spatial planners and innovation and service delivery actors who are diverse, ranging from large design and construction companies, architects, designers, building professionals, appliance companies and the emerging players in the IoT and smart metering market.

As the final segment in the chain, households are key agents of change in the energy service demand space (figure 5 and annex F). Actions taken by households could include reduced wastage (switching off lights and appliances when not in use), shift to more alternative modes of service provision through feedback from installing smart devices and adopting renewable energy. Behaviour is influenced by diverse factors including conformity to others (Walzberg *et al* 2019), organizational culture (Lourenço *et al* 2019), education and other social and cultural factors. For instance, transforming organizational culture including incorporating sustainability in school curricula was found to have significant impacts on students' mindsets (Franquesa-Soler and Sandoval-Rivera 2019, Goldman *et al* 2018). A study on light metering in Portuguese schools revealed opportunities to reduce lighting energy use with more use of daylight (Lourenço *et al* 2019). School authorities could carry out such monitoring exercises to identify areas for potential actions. Architectural and energy efficiency improvements, in addition to reduced energy consumption and associated cost savings, also improve indoor air quality and health benefits, and provide a range of other positive social benefits including enhanced user awareness (Matic *et al* 2016). The role of universities and research organizations is important both to assess the impact of existing mitigation actions, the potential of future actions and also to fill the gaps in understanding of ASI category and their impacts. A review on green buildings between 2000 and 2016 identified green and cool roofs, vertical greening systems, life cycle assessment and rating systems and ICTs among the prominent mitigation action areas in research (Zhao *et al* 2019).

Studies show participants lack awareness or have inadequate or incorrect information regarding appliance use leading to wasteful behavior (Withanage *et al* 2016). Cheah *et al* (2018) propose a framework based on three criteria: (a) reframing sustainability as a future of others' to 'present for us', (b) responsible consumption and (c) consumption feedback to encourage responsible electricity consumption. Providing online and active feedback on energy consumption can drive behavior change (Ahvenniemi and Häkkinen 2019). These can be overcome by actions that can direct change through 'product or system led innovations' or 'behavior-led' to direct users toward more sustainable behavior. The diverse stakeholders in the building sector often make upscaling challenging as many of these solutions require cooperation among multiple actors. Often a single organization/actor can make a powerful change as evidenced through the example of successful actions in educational institutions. Sustainable decarbonization of the building sector hinges on

a combination of technology and social measure and would require ambitious and simultaneous effort from policymakers, spatial planners and households to facilitate an equitable transition (figure 5).

4. Discussion

We could successfully bin the mitigation actions in ASI categories. How each one is linked to SDGs is also done. We could link each of these to SDGs and identify actors for each mitigation action for each study. Binning of the literature by country was also carried out. Table 1 provides concrete examples in each ASI category. However, in many policy dialogues, knowledge dissemination workshops we came across two most frequently asked questions (FAQs): which action is connected with the maximum number of SDGs and how to compare that across actions? And the second question is that the larger the spread of the actor network, the harder it is to coordinate, so how can we know the size of the actor pool that drives various actions? So, in this section, we present three graphical views to answer these FAQs for three sectors (section 4.1). Also, we discuss inter-sectoral linkages (section 4.2) and the impact of digitalization (section 4.3).

4.1. Sector-specific discussion: relative SDG link and spread of actor network

Figure 6 shows that all of the *shift* category actions are positively linked with more than 50% of the SDGs; shared mobility and EVs in *improve* categories are positively linked to 50% of SDGs but are also not devoid of negative linkages. All actions in *avoid* categories are linked to less than 50% of SDGs, but are devoid of any negative linkage and also need a lower spread of actor network and so are easier to implement with relatively less coordination need. Public transport requires the involvement of 100% of the actors and therefore needs more effort in coordination.

In figure 7 we notice the least trade-offs with SDGs of various actions except for the two in the *improve* category, materials efficiency and smart energy management. *Avoid* and *shift* categories of actions have all positive SDG links and no trade-offs but with a maximum of 50% of SDGs. Except for technological efficiency improvements, actor network needs are also relatively smaller and less than 50%.

In figure 8 it is interesting to note that in the building sector interventions, the *avoid* category have the maximum of positive SDG links with some minor trade-offs, but the actor network is also relatively larger compared to others. However, in the *improve*

Table 1. Wider impact of different sectoral interventions. SDG icons reproduced with permission from <https://www.un.org/sustainabledevelopment/>. The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States.







SDGs	Sector	ASI categories	Synergies (+), trade-offs (–) and uncertain impacts (\pm)	Evidence (also refer to supplementary file)
	Transport	Shift	+ Using active modes (cycling) generates income for the local communities + Active transport modes are low-cost methods for accessing basic services	(Gilderbloom <i>et al</i> 2016, Skayannis <i>et al</i> 2019, Macmillan <i>et al</i> 2020)
	Building	Shift	+ Switch to clean energy can help reduce poverty	(Poblete-Cazenave and Pachauri 2018, Rosenthal <i>et al</i> 2018)
	Transport	Shift	+ Shift to active travel (walking and cycling) increases physical activity leading to reduced mortality + Replacing car trips with active modes can contribute to targets relating to non-communicable disease; road traffic injury – Traffic crashes discourage the use of cycling	(Doorley <i>et al</i> 2015, Lin <i>et al</i> 2018, Schneider and Willman 2019, Useche <i>et al</i> 2019, Macmillan <i>et al</i> 2020)
		Improve	+ Using low or no-carbon fuel and efficient car help in reduced air pollution which delivers direct health benefits.	(Yang <i>et al</i> 2018)
	Industry	Improve	+ Optimization of building energy system with waste heat from industry for better thermal comfort	(Safaei <i>et al</i> 2015, Fraccascia 2019)
		Avoid	+ Choice in favour of improved lighting, ventilation, architectural design to avoid artificial air conditioning need to enhance thermal comfort, improve indoor air quality and therefore have consequent benefits for health and well-being	(Romero-Pérez <i>et al</i> 2017)
	Building	Shift	+ Clean cooking improves indoor air quality and overall well being	(Poblete-Cazenave and Pachauri 2018, Rosenthal <i>et al</i> 2018, Batchelor <i>et al</i> 2019)
		Avoid	\pm While green buildings by design are expected to improve indoor air quality, in some cases, green building certifications and green products may not necessarily promote indoor air quality and in some cases result in adverse outcomes through exposure to hazardous substances	(Steinemann <i>et al</i> 2017)
	Transport	Shift	+ Urban environments that enable active travel modes for trips have the potential to reduce physical and financial barriers to participating in education for women	(Bigerna <i>et al</i> 2019, Macmillan <i>et al</i> 2020)
	Buildings	Avoid	+ Better indoor air quality and thermal comfort in school buildings could improve the students' performance and help make sustainable lifestyle choices	(Hu 2017, Franquesa-Soler and Sandoval-Rivera 201, 2019, Goldman <i>et al</i> 2018)

Table 1. (Continued.)




SDGs	Sector	ASI categories	Synergies (+) and trade-offs (–)	Evidence (also refer to supplementary file)
	Transport	Shift	+ Digitalization has helped women use more carpooling due to the built-in safety features + Urban environments that enable active travel modes for trips have the potential to reduce physical and financial barriers to participating in education for women + Scaling up active modes (through careful local urban design and transport planning) can reduce gender inequities in access to basic services, healthcare and education	(Arora <i>et al</i> 2016, Mitra and Nash 2019, Macmillan <i>et al</i> 2020)
		Improve	– Females in the age group of 35–45 is reluctant to join vehicle sharing as they have to drop their children at school	(Malodia and Singla 2016)
	Buildings	Shift	+ Incentives to shift to cleaner cooking fuels has a significant benefit to women from reduced indoor air pollution and overall well-being	(Poblete-Cazenave and Pachauri 2018, Rosenthal <i>et al</i> 2018)
	Industry	Avoid	+ As water is used to convert energy into useful forms, the reduction in industrial energy demand can lead to reduced water consumption and waste water, resulting in more clean water for other sectors + Efficient water management under industrial symbiosis help in improved utilization of water resources	(Menato <i>et al</i> 2017, Fraccascia 2019)
	Buildings	Shift	+ Building design can help reduce energy and water demand, and waste water generation through building design	(Poblete-Cazenave and Pachauri 2018)
	Transport	Shift	+ Commuting through public transport and using active modes save energy	(Trinh and Linh 2018, Sovacool <i>et al</i> 2019)
		Improve	– EVs still consume a considerable amount of energy and contribute to other external effects such as congestion	(Langbroek <i>et al</i> 2017)
	Industry	Shift	– In some cases, technologies like additive manufacturing may lead to higher consumption of electricity if not operated efficiently	(Liu <i>et al</i> 2018)
		Improve	+ Various energy efficiency measures and technological innovation contributes in avoid some energy use in industry and thereby contribute in total supply pull of energy and improved energy supply	(Javied <i>et al</i> 2015, Matinaro <i>et al</i> 2019)
	Buildings	Shift	+ Access to modern energy fuels especially for cooking is among the most significant aspects of a transition to clean energy	(Poblete-Cazenave and Pachauri 2018, Rosenthal <i>et al</i> 2018)
Improve		– Building Integrated Photovoltaic (PV), distributed renewable generation and solar water heaters help achieve targets under SDG 7	(Mbakwe 2016, Salpakari and Lund 2016)	

(Continued)

Table 1. (Continued.)




SDGs	Sector	ASI categories	Synergies (+) and trade-offs (–)	Evidence (also refer to supplementary file)
	Transport	Shift	+ Shifting toward active modes esp. bike/cycles increase demand for bike repair shops, bike parking which enhances employment opportunities	(Gilderbloom <i>et al</i> 2016)
	Industry	Avoid	+ Industrial symbiosis promote industrial innovation through technology, hence creates new decent job opportunity	(Safarzadeh and Rasti-Barzoki 2019)
	Buildings	Shift	+ Enhanced efficiency and reduced consumption reduce costs for households. + Better indoor environment enhances productivity	(Ahvenniemi and Häkkinen 2019)
	Transport	Avoid	+ Proper infrastructure encourages transit-oriented development and avoid ownership of private vehicles	(Khan <i>et al</i> 2016, Sjöman <i>et al</i> 2020)
		Shift	+ Shift to active travel mode and acceptance of public transport needs adequate infrastructure – In developing countries weather conditions and unreliable connectivity affect the lack of incentives to improve existent public transportation. Also lack of proper service delivery like dirty station, rude staff, low-quality buses, less safety, careless bus drivers and ticket controllers inhibit shift to public transport	(Bonasif 2017, Lelono <i>et al</i> 2018, Trinh and Linh 2018, Carroll <i>et al</i> 2019, Wethyavivorn and Sukwattanakorn 2019, Whittle <i>et al</i> 2019)
		Improve	+ Shared mobility offers potential for technological innovation (app-enabled ride sharing) + Larger penetration of electric vehicles requires innovative business models	(Ma <i>et al</i> 2018a, 2018b)
	Industry	Improve	+ Promotion of industrial innovation through technological upgradation, energy efficiency, industrial networking system and clustering act as a demand-side mitigation actions to reduce energy demand in industrial process	(Ashraf <i>et al</i> 2018, Guo <i>et al</i> 2018, Hens <i>et al</i> 2018, Safarzadeh and Rasti-Barzoki 2019)
	Buildings	Improve	+ Research in energy systems, monitoring devices including smart-grids, smart-meters, flexible technology combinations spur green innovations	(Boßmann <i>et al</i> 2015, Salpakari and Lund 2016)
	Transport	Shift	+ Access to bicycle lanes or cycle tracks increase the odds of female commuters using bicycles + Digitalization has helped women use more carpooling due to the built-in safety features	(Arora <i>et al</i> 2016, Mitra and Nash 2019).
	Buildings	Improve	Inequitable access to cooling, especially with reference to air conditioning will result in energy poverty and undermine SDG7	(Mastrucci <i>et al</i> 2019)

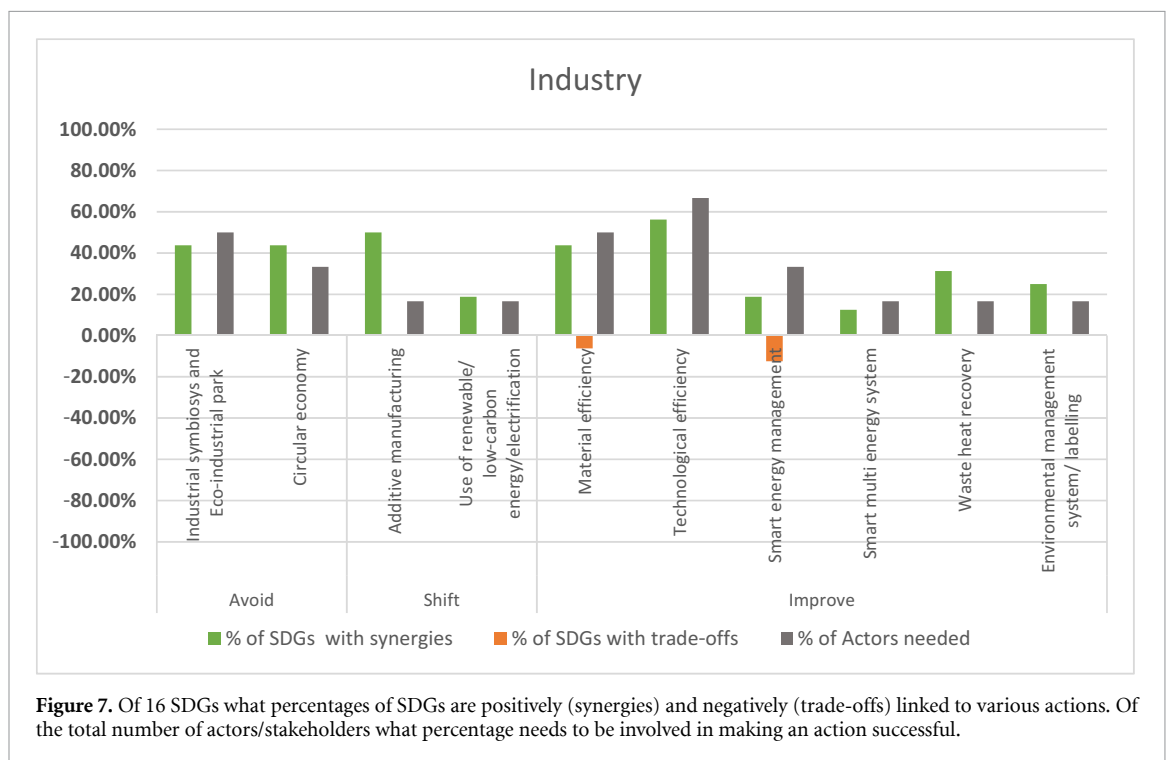
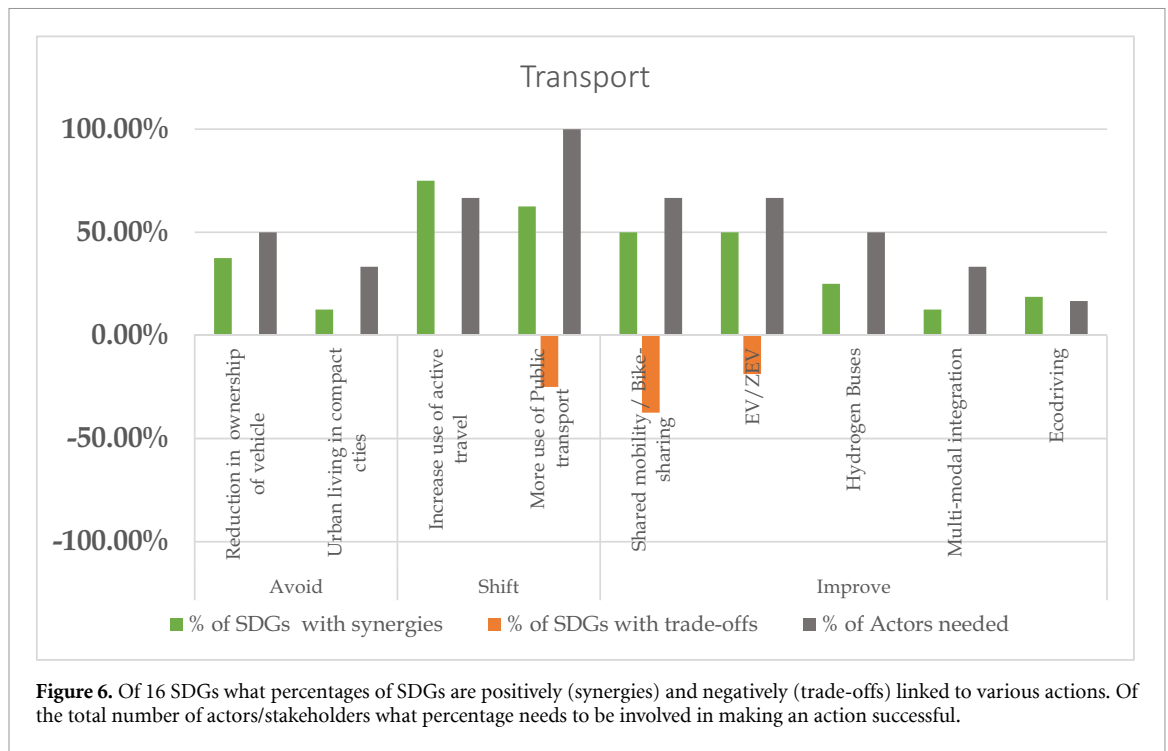
Table 1. (Continued.)

SDGs	Sector	ASI categories	Synergies (+) and trade-offs (–)	Evidence (also refer to supplementary file)
	Transport	Avoid	+ Proper infrastructure encourages transit-oriented development and avoid ownership of private vehicles	(Khan <i>et al</i> 2016, Sjöman <i>et al</i> 2020)
		Shift	+ Expanding public transport and decreasing private vehicle ownership reduces congestion fostering sustainable cities	(Fenton 2017)
	Industry	Avoid	+ Use of by-products through circular resource management system helps in avoid demand of virgin raw materials in industrial process	(ElMassah 2018)
	Buildings	Avoid, Shift, Improve	+ Sustainable design and construction of buildings including the use of renewable energy technologies such as solar lead to sustainable cities and communities – Non-committal policy for green roofs is not an effective way to prepare cities sufficiently for future climate changes	(Ascione 2017, Balaban and de Oliveira 2017, Alawneh <i>et al</i> 2018, van der Meulen 2019)
	Transport	Avoid, Shift, Improve	+ Sharing mobility/reducing car ownership/using EV help to move toward sustainable consumption	(Chardon 2019)
	Industry	Avoid	+ Material efficiency in industry can be achieved through sustainable consumption of raw materials and other inputs of production like water and energy	(Menato <i>et al</i> 2017, ElMassah 2018, Shahbazi <i>et al</i> 2018, Soo <i>et al</i> 2018, Meskers <i>et al</i> 2019)
			+ On the demand side sustainable consumption will lead to avoid demand of some manufacturing goods – High price of renewable virgin material leads to more consumption of non-renewable materials – Mitigation actions in transport sector like EV and light weight vehicle may increase demand for some virgin material in automobile sector	
	Buildings	Avoid	+ Green buildings including elements of passive construction, water and energy efficiency help achieve SDG 12 goals	(Alawneh <i>et al</i> 2018)
Shift		+ Innovation in IoT and smart metering raises awareness and can reduce consumption – Higher efficiency could potentially lead to rebound effect	(Cetin and Kallus 2016, Casado-Mansilla <i>et al</i> 2018)	
Shift, Improve		+ Responsible consumption from appliance, purchase, solar PV for self-consumption and use of energy efficient appliances	(Abdessalem and Labidi 2016, Mizobuchi and Takeuchi 2016)	
	Buildings	Shift	+ Clean cooking fuels reduce environmental burdens associated with biomass use + The benefits of shift to Liquefied Petroleum Gas (LPG) need to be evaluated against the impacts of LPG extraction and processing. Also, LPG could entail additional costs for poorer households	(Rosenthal <i>et al</i> 2018)

(Continued)

Table 1. (Continued.)

SDGs	Sector	ASI categories	Synergies (+) and trade-offs (–)	Evidence (also refer to supplementary file)
	Transport	Avoid/Shift	+ Shifting to active modes and reducing car demand preserve land that would have been otherwise used to construct and maintain parking garages and surface parking lots	(Gilderbloom <i>et al</i> 2016)
	Transport	Avoid	+ Policies (including vehicle registration tax, parking costs) focusing on sustainable transportation can reduce vehicle ownership	(Khan <i>et al</i> 2016, Wethyavivorn and Sukwattanakorn 2019)
		Shift	+ Policy makers should jointly promote public transport and the benefits of using active mode	(Ceccato and Diana 2018)
		Improve	+ Policies like subsidizing electric vehicles for greater adoption, odd–even car rule help in promoting sustainable transport habits – Subsidies may lead to higher sales among the active travellers	(Rudolph 2016, Zhang <i>et al</i> 2018)
	Industry	Improve	+ Emergence of stronger financial institutional mechanisms to provide support in form of tax deduction and subsidy to encourage the use of energy efficient and clean technology	(Pillay and Buys 2016, Bertarelli and Lodi 2019)
	Transport	Avoid	+ Multiple stakeholder partnerships are important for reducing vehicle ownership	(Wethyavivorn and Sukwattanakorn 2019)
		Shift	+ Multiple stakeholder partnerships are important for widespread adoption of the public transport system + Scaling up active modes requires the development and strengthening of transdisciplinary partnerships for planning	(Rarasati and Iskandar 2017, Macmillan <i>et al</i> 2020)
		Improve	+ Policies like subsidizing electric vehicles for greater adoption, odd–even car rule help in promoting sustainable transport habits – Subsidies may lead to higher sales among the active travellers	(Rudolph 2016, Zhang <i>et al</i> 2018)
	Industry	Avoid	+ Symbiotic relationship among stakeholders is a key factor to run a successful industrial cluster	(ElMassah 2018, Huang <i>et al</i> 2019)
	Buildings	Avoid	+ Co-design and development of energy solutions and mentorship using local and indigenous knowledge can enable higher adoption	(Franquesa-Soler and Sandoval-Rivera 2019)

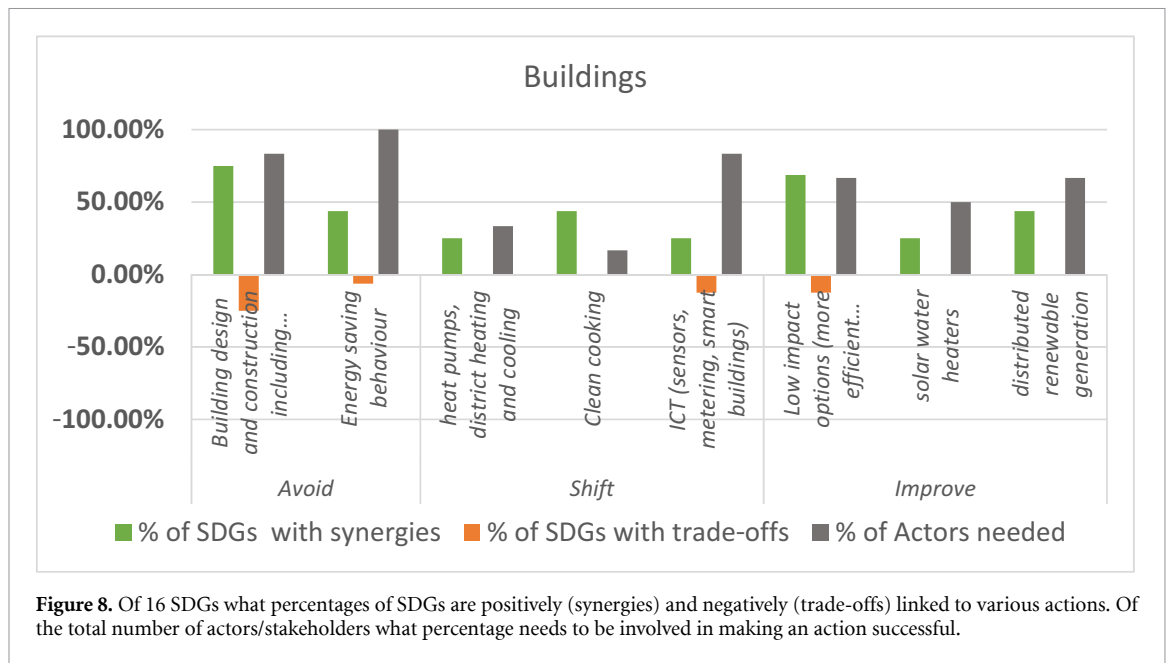


category, the actor network needed for efficient appliances is more compared to others in the category, but SDG links are also more. Some actions such as clean cooking, heat pumps and district heating have all positive SDG links.

This analysis provides very useful insights which are novel in this study and provides a useful guide for policymakers, and for that matter for any of the decision makers.

4.2. Interaction across sectors

For actions toward sustainable urban mobility, adequate and well-designed road infrastructure and compact urban planning are essential. especially public transport and non-motorized transport. This helps in attracting new residents because of reduced transportation costs, and increases their willingness to pay for the property. This increases housing property prices and governments can earn additional tax



revenue (Shen *et al* 2018). A case-study from Seattle based on four completed bus transit-oriented development projects reveals that the value of the houses within 0.5 miles radius of the projects has increased significantly (Shen *et al* 2018). Also, increasing travelers' willingness to adopt active modes largely depends upon the built-in facilities (walking and biking lanes, the distance between buildings and transit shops). Both transit-oriented development and acceptance of active modes demand joint action from the construction industry and the planners (road and urban). Also, the construction industry is innovating ways to build infrastructure that can facilitate the needs of sustainable mobility like the use of rubberized asphalt concrete to improve the performance of pavements (Wang *et al* 2018a) and the use of recycled concrete aggregate as the base course of new pavements (Reza *et al* 2018).

The industry sector has obvious backward linkages in supplying end-use products to the transport and buildings. Consequently, demand changes in these sectors directly impact industrial production. For example, circular economy principles such as recycling of construction waste, sharing economy such as shared workspaces, etc reduce the demand for built space (Liu and Lin 2016). The transition toward clean mobility impacts the demand for non-ferrous metals, in some cases leading to an adverse impact on material consumption and in a broader context of environmental sustainability. EV will increase demand for lithium, cobalt and nickel for battery manufacturing (Meskers *et al* 2019) and manufacturing of lightweight vehicles will result in increased demand for aluminum (Soo *et al* 2018). Industry being part of the societal transition plays an

important role in enabling this transformation. An important linkage between buildings and industry is the use of waste heat from industrial production for heating buildings (Safaei *et al* 2015).

A number of studies have examined the life cycle impacts of building materials and implications for the construction industry (Muller *et al* 2019). Sustainable construction practices including the use of alternate building material options include substitution with fly ash, wood, and local materials, recycling and re-use of construction waste and extending building lifetimes have a significant impact on the industry sector through the demand and production of energy intensive materials such as steel and concrete (Dhar *et al* 2020). Urban planning and design actions including compact urban form, transit-oriented development, and vehicle to grid are examples where buildings and transportation intersect.

4.3. Digitalization

Information and communication technologies have emerged as one of the biggest enablers of various demand side changes in all the three sectors through improved interconnectedness, information sharing and use of artificial intelligence.

Shared mobility is used by commuters is gaining wider acceptance and it is made possible due to digitalization. Various 'apps' are available for sharing cabs (e.g. Uber, Ola, Grab, Lyft), owned cars (e.g. sRide in India, Baha, Pathao in Bangladesh, BlaBlaCar in Europe) and bikes (e.g. Mobike in China, Gojek in Indonesia, Thailand). The biggest carpool and bike pool app in India, sRide has made office commutes convenient and led to 80% of the transportation cost

savings for commuters (sRide 2019). This app offers various features like a safety toolkit, real time tracking and 24 × 7 customer support. They help coordinate transport for commuters on the same route. Commuters from densely populated Indian cities like Mumbai commented that they find their service on sRide (2019) hassle-free, timely, economical and safe. Liu (2018) reported that commuters in China used Mobike to travel a total distance of 5.6 billion km in 2016 nearly equivalent to 1.26 million tons of carbon emissions. Smart transportation with the help of IoT is not only making daily commute economical, easy and safe but also reducing carbon footprint (Pirimuthu and Zhou 2016).

For industrial demand, digitalization itself is not a mitigation action, but it enables optimization of energy use in industrial processes through enhanced energy efficiency with improved information sharing (ElMassah 2018), help in the development of additive manufacturing (Nascimento *et al* 2019) and industrial communication networking system (Liu *et al* 2015). At the consumer end, digitalization has enabled the creation of an alternative form of provisioning for clothes swapping through various apps, and also creating pop-up marketplaces (Holmes 2018). Dedicated websites for clothes swapping, like 'swishing.co.uk', 'swopped.co.uk' or apps like 'This for That', have provided a new marketplace for used clothes (Holmes 2018) and also contributed to avoiding the demand for new clothes and hence the textile industry. The use of digital media in daily activities like switching to electronic newspapers is reducing demand for paper newspapers (Permatasari *et al* 2018).

The building sector has seen an increasing focus on 'smart buildings', 'intelligent buildings' that include a significant level of automation at the end-user level, device-level or system level. This includes the use of ICTs that can measure, record, and influence operations (Fabi *et al* 2017). A number of studies show smart meters and sensors that provide real-time information on energy consumption or enable digital building–occupant interactions to enhance awareness of users and can assist the shift toward sustainable consumption (Jensen *et al* 2018). A recent study also showed that state-of-the-art equipment that provides specific feedback on user behavior can enable sustained behavior change.

5. Conclusions

For a long time, the discourse on climate change mitigation action has focused on the supply side mostly around technological advancement and/or fuel change. With rising urgency in accelerated mitigation action in a short period of time, literature is also focusing on the role of demand side solutions in climate change mitigation. Specifically,

in the transition phase how demand can be avoided, shifted or improved to scale up and accelerate the momentum of mitigation actions. In the forthcoming IPCC Sixth Assessment report, an entirely new chapter is dedicated to demand and services besides usual end use demand sectors. The report also frames climate change mitigation in the context of sustainable development. The systematic search for evidence in the present study is based on systematic screening of literature relevant to the demand side of the mitigation actions for transport, industry and building and makes a unique contribution by synthesizing the existing studies from 2015 by three layered analytical framing. This study generates information that can help the new assessment report.

A compilation of demand side actions across sectors needs a common and comparable approach. The ASI category is one such framing that offers the advantage of comparability. While it has so far been applied extensively to the transport sector, the paper attempts to use this framing to collate actions in all three major demand side sectors—transport, buildings and industry. Secondly, the aim was to understand how various actors need to play their roles in various categories and how such actions are linked to wider goals under SDGs.

Findings clearly show that upscaling actions for mitigation would require combined efforts among policymakers, and various stakeholders like households, individuals, city planners, and educators. There is a clear scope for exploring new ways of organizing businesses/services taking advantage of options that create small local supply chains and also with a role for digitalization megatrends in certain fields of actions. Also, cross-sectoral collaboration, resource sharing and information exchange accelerate mitigation outcomes. The study identifies the key enabling factors and actors that can facilitate such a change. The role of governments in incentivizing these solutions through targets, performance standards, and regulatory instruments like tax exemption, subsidy, new pricing policies, monitoring compliance is obvious. A survey of 43 professionals on green buildings (Darko *et al* 2017) indicated that implementation of standards for design and construction was the most significant factor driving the adoption of green building technologies, followed by factors such as benefits of energy efficiency, health and well-being, resource conservation and reduced lifecycle costs. For avoiding mobility demand and shifting to active modes and public transport, government and spatial (city) planners are the key actors and help in avoiding service demand and emissions. For the industry sector to create a symbiotic relationship among the firms, facilitating the role of the IS and EIP operators and policy support from the government is crucial. Strengthening of the financial

institution with innovative financial support mechanism is also needed. The role of research organizations is also important to develop a knowledge base for the possible use of by-products and technological development.

Behavioral change is often constrained by non-behavioral factors like policy, education, and infrastructure. Especially high upfront costs of low carbon options, inadequate infrastructure, incorrect understanding or low awareness regarding sustainable options and socio-cultural factors define behavioral choices. A better understanding of the costs and benefits of these solutions could facilitate higher adoption.

Implementation of mitigation actions that can help stabilize global warming at 1.5 °C has multiple synergies across a range of sustainable development dimensions. Not surprisingly, we find a number of actions across all three sectors that offer opportunities to deliver simultaneous benefits for climate change and SDGs. Clean cooking fuels, investments in public transport and sustainable and green buildings are examples of such solutions. All *avoid* actions and most of the *shift* actions entail reduced consumption while most of the *improve* actions result in responsible consumption therefore aligning with SDG 12.

Most of these demand side mitigation actions showed positive linkages with SDGs 7, 9 and 11. The recent upscaling of digitalization offers sizeable opportunities for industrial innovation. Initiatives such as active transport, passive design, cleaner cooking fuels could offer the same level of service with additional synergies (co-benefits) across several SDGs.

The review brings out several studies that point to the need for looking at the longer term in a sustainability context. A case in point is green buildings where performance could possibly decline over time and this can only be reviewed through long-term monitoring studies (Zaid et al 2017, Ge et al 2018). Similarly, the rebound effect of energy efficiency occurs over time and should be an important consideration in designing energy policies. Similarly, switching to cleaner cooking fuels is a special case where the transformation needs to be viewed beyond its energy benefits as it delivers significantly wider benefits for gender equity and development in low- and middle-income countries.

Although the review was limited to only one database, Scopus, findings present evidence of the diversity of actions including emerging innovations that reduce energy consumption, generate cost savings and offer sizeable opportunities to achieve targeted benefits. Digitalization through ICT and IoT has emerged as a significant enabler of various demand side mitigation actions. There are case

studies to show that technologies such as ride-sharing in transportation, enhanced efficiency to smart buildings, appliances and smart meters have enhanced service delivery, while reducing material consumption and CO₂ emissions in the app sector are some examples.

Several actions including public transit, industry clusters or district heating are enabled by integrating into existing planning regulations. Spatial planners (e.g. urban planners and architects) through planning interventions including zoning, land use changes, passive design strategies have a significant influence to shape urban form to a more sustainable and climate responsive one. Emerging developments in ICT provide for a significant opportunity for industrial innovation in devices and services.

One important finding of this study is that demand side actions cannot be effective enough in isolation. For optimizing the mitigation actions, the interconnectedness across sectors is important. Demand side mitigation actions in the transport sector are highly dependent on city planning and infrastructure and the construction sector is an integral part of the building sector. However, for the industry, it is found that some demand side actions of other sectors have some trade-off in industrial production. In order to achieve an overall emission abatement, it is important to develop a cross-sectoral framework. Similarly, technological solutions can be more effective if complemented with sustainable behavioral responses of end users.

The success of many of the demand side actions depends on the willingness of people to modify their behavior, which is rooted in complex economic, social and cultural circumstances besides the design of built structures. Studies have also highlighted the challenges and complexities involved in switching to a sustainable lifestyle (Konrad 2015). In many cases, it is a lack of awareness or incorrect understanding and these can be corrected by enhancing awareness, through better reporting and feedback on consumption. Organizations could play a significant role in shaping behavior by monitoring and understanding consumption habits to set a sustainability culture, through regulations and targets such as switching off appliances when not in use, reducing personal electricity consumption, bike to work, etc. Educational institutions such as schools and universities have a significant role to play by incorporating sustainability into curricula, empowering students to make sustainable lifestyle choices, and through research and living labs, offer a testbed for potential solutions that can co-deliver mitigation and well-being within the premises but also at a wider spatial scale to neighborhood and the city and temporally

by shaping mindsets of occupants toward responsible consumption.

We have adopted a semi-systematic but comprehensive review method where we have systematically searched and screened the existing huge body of literature using the Scopus database and only literature in the English language. This is because performing a full systematic review is time-consuming, resource-intensive, focuses on a narrow range of questions and also prevents in-depth analysis (Sovacool *et al* 2018). However, studies also suggest that the use of a few more databases ensures adequate coverage (Bramer *et al* 2017). We are aware of this limitation in our study but we feel that this study has attempted to deliver a comprehensive in-depth analysis of demand side mitigation actions and SDGs, and actors' role. Most studies identify benefits that could indirectly contribute to SDGs, while few studies directly establish linkages with SDGs, especially at the target level covering the study period. The findings from several case studies are context specific. The study recognizes that SDG relationships are complex and often not easily quantifiable, non-linear and vary across time. Few studies look at impacts of mitigation pathways, policies and actions on reducing poverty, affordability of technologies and equity impacts. Future studies could take a deeper look into understanding these complex interlinkages, especially spatial and temporal trade-offs between mitigation and SDGs, and maybe also in many other country contexts.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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Annexures

Industry: The demand for manufactured goods can be divided into two categories: intermediate demand and final demand. The intermediate demand comes from within the industrial system as raw material and is categorized under shift and improve categories. Avoiding demand for industrial products and services is driven by the final consumer, and is therefore considered as an additional search term.

Annex A. List of search terms used.

Transport	<p>Query 1 (Population): transport* OR vehicle OR travel OR *mobil*</p> <p>Query 2 (Intervention):</p> <p>Technical and Infrastructural change: 'active travel' OR ('intermodal' AND ('travel' OR 'transport')) OR 'EV' OR ('electric' W/1 ('car' OR 'vehicle' OR 'taxi' OR 'rickshaw')) OR eco-driv* OR 'small* vehicle*' OR 'lightweigh* vehicle*' OR 'rickshaw*' OR 'bio-based diesel fuel' OR 'bio fuel' OR 'hydrogen fuel' OR ('public' W/3 ('trans*' OR 'bus')) OR ('bus' OR 'metro' OR 'subway' OR 'train' OR 'light rail' OR 'heavy rail' OR 'tram' OR 'railway') OR ('bicycle lane*' OR 'bi-cycle lane*' OR 'bicycle track*' OR 'bi-cycle track*') OR 'rapid transit' OR ('bicycle' OR 'pedestrian*' OR 'walking' OR 'cycling' OR 'rickshaw*') W/2 ('infrastructure*' OR 'path' OR 'paths' OR 'trail*' OR 'network' OR 'route*' OR 'corridor*' OR 'lane*')</p> <p>Behavioral change: (('car' OR 'vehicle' OR 'automobile') AND ('use*' OR 'usage*' OR 'using' OR 'purchas*' OR 'buy*' OR 'choice' OR 'shar*' OR 'preference') AND ('behavi*' OR 'response')) OR 'modal shift' OR 'park and ride' OR 'bicycle shar*' OR 'bik*' OR 'car pool*' OR 'pedestrian*' OR 'walk*' OR 'bicycl*' OR 'cycl*' OR ('response' W/3 'congestion charge')</p> <p>Query 3a (Outcome): cost* OR 'trade-off*' OR *benefit* OR 'co-benefit*' OR synerg* OR *link* OR interact* OR *connect*</p> <p>Query 3b (Outcome): 'SDG*' OR 'Sustainable Development' OR 'sustainable development goal*'</p>
Industry	<p>Query 1(Population): Industr* OR manufact* OR product* OR sector*</p> <p>Query 2 (Intervention):</p> <p>Technical and Infrastructural change: 'Carbon dioxide capture' OR 'Carbon dioxide utilization and storage' OR CCS OR CCU OR 'energy efficiency' OR 'eco industr*' OR cluster OR 'industrial symbiosis' OR 'eco innovation' OR '*industrial park*' OR circular* OR 'circular econom*' OR remanufacture* OR 'green industr*' OR tax* OR 'carbon tax' OR 'strategic management'</p> <p>Behavior/demand-specific ('energy demand' OR 'energy W/1 reduc*' OR 'energy W/2 consumption' OR respon* OR shar* OR preferenc*) AND behavi*</p> <p>Query 3a (Outcome): cost* OR 'trade-off*' OR *benefit* OR 'co-benefit*' OR synerg* OR *link* OR interact* OR *connect*</p> <p>Query 3b (Outcome): 'SDG*' OR 'Sustainable Development' OR 'sustainable development goal*'</p>
Building	<p>Query 1(Population): Residential OR commercial OR office OR hous* OR home* OR building* OR envelop* OR indoor* OR room OR hospital OR school</p> <p>Query 2 (Intervention):</p> <p>Technical and Infrastructural change: 'thermal comfort' OR 'heat*' OR 'cool*' OR 'low embedded energy' OR 'passive house' OR 'net zero' OR 'mixed mode' OR 'zero energy' OR 'green building*' OR 'green design' OR 'sustainable design' OR 'smart meter*' OR ('low-carbon' W/2 'materials')</p> <p>Device-specific (appliance* OR light* OR 'air condition*' OR 'refrigerat*' OR 'cook*' OR 'electrical device*' OR 'energy service*' OR 'electricity') AND</p> <p>Behaviour/demand-specific (use* OR purchas* OR buy* OR choice* OR shar* OR preferenc* OR 'consumption' AND 'behavio*r') OR ('lifestyle' OR 'rebound')</p> <p>Query 3a (Outcome): cost* OR 'trade-off*' OR *benefit* OR 'co-benefit*' OR synerg* OR *link* OR interact* OR *connect*</p> <p>Query 3b (Outcome): 'SDG*' OR 'Sustainable Development' OR 'sustainable development goal*'</p>

We used * for wildcards.

Annex B

- Title: Presence of specific sector names or their synonyms. Mention of mitigation actions that the authors later identified as ASI category
- Abstract: In addition to the criteria for title selection, mention of implementation of the actions, hint of cross-sectoral linkages or deep decarbonization or zero emission

- Full text: At this level the selection criteria is narrowed down to articles that aligned with the research question. These would include ASI mitigation actions for transport, industry and buildings, evidence of implementation and including mention of sustainable development or sustainable development goals or sustainability. Experimental, modeling and lab-based studies were excluded from the final analysis.

Given the diversity in the demand among these three sectors, apart from these general criteria for selection, we have also followed some sector-specific criteria.

Transport: While screening through the titles, specific mention of supply chain, manufacturing or related words, vehicle design, microgrids integration of electric vehicles, distribution grids in presence of EVs charging stations are excluded. During screening through abstracts along with all those mentioned in title screening and power flow analysis, studies regarding life-cycle of batteries assessment, implementing dual fuel, EV batteries recycling, rail-line or pavement or road construction materials or maintenance, choice between sustainable mobility plans by policy makers are excluded. At the third stage of screening we excluded studies which did not include sustainability/sustainable development/SDGs.

Industry: Title screening included articles which mention any of the eight major CO₂-emitting industries mentioned in IPCC AR5, namely, iron and steel, cement, chemical, pulp and paper, non-ferrous metal, food processing, textile and leather and mining or manufacturing industry as a whole. Articles on all other industries are excluded. At the abstract screening stage, studies relating to business models for mitigation actions, life cycle analysis (LCA) are excluded. While screening full text studies, we excluded studies that did not specify any specific demand side actions. Studies regarding SME other than manufacturing industry are excluded. Industrial park design and business sustainability are also excluded. We have excluded experimental studies particularly those which do not have any implementation in real world settings.

Additional literature has been selected from the results of a separate search in Google Scholar for

the industrial linkage of some specific demand-side actions such as the change in demand for pulp and paper industry with increase in electronic newspapers, reduced textile demands from increase in clothing longevity, reuse and recycling of textiles, and altered cement demands from the use of wood ash. These additional literatures are included based on the authors' knowledge from grey literature, news items of emerging actions on demand reduction at the end-user level and as we were looking for very specific actions, in Google Scholar we were getting more explicit targeted results.

Building: Title screening involved screening of papers which included studies specific to buildings sector and mitigation actions on the demand side. This would automatically exclude studies on other sectors such as transport and industry, as well as supply side actions. At the abstract screening stage, a number of studies were found to focus on construction materials. These were screened out since these would involve substitution with other materials and therefore are addressed in the industry sector. Studies involving economic dimensions including costs and benefits of mitigation actions and those relating to the wider context such as modeled future urban scenarios were not considered. Similarly, papers that included theoretical studies except for literature reviews, such as desk research, lab experiments, simulations or modeling exercises and did not offer evidence of implementation were excluded. For example, new and innovative experiments involving alternate materials, thermal properties, new designs and approaches for construction and simulations of energy consumption were not considered. An additional search was conducted to include articles specifically on clean cooking, since this is an important dimension and was not captured in the original Scopus search.

Annex C. Articles included after each screening stage.

Screening stage	Count	
	included ^a	Excluded
Stage 1: Identification		
Identified from Scopus using queries listed in annex A Transport = 2284, Industry = 2951, Building = 2012	6887	
Stage 2: Eligibility for inclusion		
After duplicates removed Transport = 1710, Industry = 2639, Building = 1981	6330	590
After title screening Transport = 590, Industry = 536, Building = 954	2080	2513
After abstract screening Transport = 176, Industry = 248, Building = 556	980	885
Full-text articles assessed for eligibility Transport = 217, Industry = 248, Building = 361	826	
Stage 3: Finally Included		
Additional records included Transport = 6, Industry = 8, Building = 10	24	
Total articles included Transport = 107, Industry = 59, Building = 128	294	

^a Sector-wise break-up for articles included are provided only.

Please see supplementary file for a detailed list of the articles included for this study.

Annex D. Mitigation actions for mobility service.

Service	Avoid	Shift	Improve
Mobility	<p>Reduction in vehicle ownership: government can</p> <ul style="list-style-type: none"> • recompense people for (voluntary) forfeit of a (second) car in the household • impose congestion charge for driving in the central of the city • impose high parking fees and high taxes on cars <p>Compact urban planning: planners can</p> <ul style="list-style-type: none"> • adopt long term strategies like increasing housing supply near workplace to avoid mobility demand • orientation of buildings toward transit stops to reduce mobility demand 	<p>Active modes: road planners/government (local) can</p> <ul style="list-style-type: none"> • promote awareness regarding using active modes • enhance road safety education for all users. • adopt measures like <ul style="list-style-type: none"> * congestion charges, * lowered speed limits, * reduced road space for cars; * 'car-free Sundays' in the city centre and some residential areas (already in Bristol). • improve the nature of the built environment to encourage people to walk and bike for their non-work travel needs <ul style="list-style-type: none"> * introduce new facilities like reserved bicycle lanes * create more walkable streets * create safer pedestrian and bicycle crossings * provide more street space bicycle facilities * constructing new cycling infrastructures • provide policies to allow entrance of bikes in train (already in Europe) 	<p>Hydrogen buses: government (local) need to</p> <ul style="list-style-type: none"> • provide proper fueling infrastructure <p>Commuters must be</p> <ul style="list-style-type: none"> • willing to pay extra: In Perugia, Italy commuters are Willing to Pay (WTP) 30% to 60% over the current single-trip bus fare to support introduction of these buses <p>Electric taxi: government (local) can</p> <ul style="list-style-type: none"> • provide subsidies to convert private taxis to electric taxis (suggested for Seoul, South Korea; China). • provide battery replacement scheme • created provision for charging facilities <p>Electric vehicle-EV/zero emission vehicles-ZEV/connected. Autonomous vehicles-CAV: road planners/government (local) can</p> <ul style="list-style-type: none"> • advertise EV's environmental benefits & reduced perceived risks to attract adopters. • increase subsidies for ZEV (as in Germany) • provide free parking, • e-road infrastructure • introduce a separate CO₂ tax, • increase fuel costs by tax elevation,

Annex D. (Continued.)

Service	Avoid	Shift	Improve
		<ul style="list-style-type: none"> • bike racks on buses • promote this for medium & long trips (as done in China) 	<ul style="list-style-type: none"> • increase available charging infrastructure • construct new infrastructures like smart highways
		Supply-chain partners can	<ul style="list-style-type: none"> • provide informational interventions to ensure individuals try to become familiar with these new technologies and modes
		<ul style="list-style-type: none"> • provide secure monitored parking space for bikes in transit stations and shopping districts • offer bike and transit packages with reasonable price • smart phone applications for pedestrians 	Supply-chain partners can
		universities can	<ul style="list-style-type: none"> • offer free trials of CAVs or new forms of shared mobility to help address misperceptions about the viability or quality of alternatives compared to current choices
		<ul style="list-style-type: none"> • promote the culture of cycling by targeting travel related attitudes and gendered-norms of mobility • provide bike safety courses, bike shop vouchers, secure bike parking and bike repair shops 	Electric boats: government (local) need to
		Workplaces/companies can	<ul style="list-style-type: none"> • provide subsidy for deployment
		<ul style="list-style-type: none"> • motivate workers (informational emails; handing out flyers) to commute to work by bike (practiced in Boston, USA) • put advertising; creative posters 	Tourists can
		Individuals	<ul style="list-style-type: none"> • pay price premiums
		<ul style="list-style-type: none"> • parental encouragement can help young users adopt cycling practices • peer encouragement can help adopt cycling practices • Users to encourage their relatives and friends 	Multi-modal integration: planners are
		Public transit (rail; metro; bus): Government (Local) can	<ul style="list-style-type: none"> • Integrating metro-rail with park-and-ride facilities: this has increased metro rail ridership in Delhi, India
		<ul style="list-style-type: none"> • disseminate knowledge and promote the values for sustainable transportation use • make transit use more affordable than driving • increase efficiency of public transit. • provide attractive travel cost (e.g. discounted ticket in China); • provide proper road infrastructure • provide public transport infrastructures in small and medium-sized cities (suggested by a study in India) 	Ecodriving:
			<ul style="list-style-type: none"> • Heavy electric vehicles drivers are motivated by the goals of environmental protection and cost reduction, and gamification aspects
			Shared mobility: government can
			<ul style="list-style-type: none"> • impose parking fee on privately owned cars. • subsidize shared modes
			Supply-chain partners (car rental service providers) are
			<ul style="list-style-type: none"> • using ICT to create app-enabled smart ride-sharing system • asking for extra verification for safety
			Commuters are
			<ul style="list-style-type: none"> • willing to use shared mobility as it is cost savings compared to public and private transport
			Bike-sharing: government (local) need to
			<ul style="list-style-type: none"> • designing free-floating bike-sharing system • bay area bike sharing scheme • improve the quality of the road surfaces and bikes, and traffic safety

(Continued)

Annex D. (Continued.)

Service	Avoid	Shift	Improve
		Supply-chain partners can <ul style="list-style-type: none"> • provide professional training for bus drivers and ticket controllers, • provide air-conditioners (China; India) and wastebaskets on board (China), • provide digital traveling services like bus route information, and schedule timetable. • provide Informative and entertaining bus stops • upgrade transportation infrastructure and quality (suggested by studies in China, Indonesia and Vietnam) Employers can <ul style="list-style-type: none"> • provide provision of monthly-prepaid public transport passes (already used in Seoul and Tokyo) rather than private transport allowances Individuals can <ul style="list-style-type: none"> • encourage their relatives and friends • parents must agree to use public transit for children's school travels 	Supply-chain partners need to <ul style="list-style-type: none"> • increase the availability of the related equipment • increase the number of stations and bike tracks • provide optimal distribution of docking stations across the city along with convenient and secure storage provisions • design quality of the bicycles and the stations; and • ease the subscribing to and using the programme. • properly manage the stations such that it is never empty (full), causing out-of-stock events for customers that want to rent (return) bikes at such stations Individuals/commuters can <ul style="list-style-type: none"> • use this to solve the first/last mile problem

Annex E. Mitigation actions for industry (manufactured goods).

Service	Avoid	Shift	Improve
Manufactured goods Intermediate demand for energy and material demand of manufactured goods	Clustering of industries through industrial symbiosis (IS) and eco-industrial park (EIP): <ul style="list-style-type: none"> • formulate policy to enhance symbiotic relation • cooperation among various government agencies Industrial practioners/IS facilitator <ul style="list-style-type: none"> • facilitate information sharing and cooperation • shared support service • maintain heterogeneity of the firms in a cluster Research institute <ul style="list-style-type: none"> • R & D for better/wider use of by-products Emerging market places through digitalization <ul style="list-style-type: none"> • influence people to adopt sustainable lifestyle 	Clean/green technology government <ul style="list-style-type: none"> • encouraging tax/subsidy policy Research institute <ul style="list-style-type: none"> • R & D and innovation Circular economy government <ul style="list-style-type: none"> • facilitation for better cooperation and sharing Research institute <ul style="list-style-type: none"> • R & D and innovation 	Additive manufacturing use of renewable/low-carbon energy/electrification industrial practioners <ul style="list-style-type: none"> • Clean/green technology government • encouraging tax/subsidy policy Research institute <ul style="list-style-type: none"> • R & D and innovation Smart energy management Industrial practioners <ul style="list-style-type: none"> • facilitation in technology adoption Smart multi-energy system Industrial practioners <ul style="list-style-type: none"> • facilitation in technology adoption Waste heat recovery government <ul style="list-style-type: none"> • formulate policy to enhance symbiotic relation and clustering Research institute <ul style="list-style-type: none"> • R & D for recovery of waste heat quantifiably Environmental management systems (EMSs) government <ul style="list-style-type: none"> • proper labelling system and it is monitoring Industrial practioners <ul style="list-style-type: none"> • through CSR activity

Annex F. Mitigation actions for building (shelter/heating/cooling/lighting) demand.

Service	Avoid	Shift	Improve
Shelter heating/cooling/ cooking/ lighting demand	<p>Building design and construction utilizing passive strategies such as shading, form and orientation of the building, natural lighting, ventilation or retrofit (avoiding demand for heating/cooling), refurbishment of old buildings/housing, green roofs construction companies/builders/architects can</p> <ul style="list-style-type: none"> work with industry stakeholders and government to improve the understanding of costs and benefits of green buildings optimise building design to maximise natural lighting, ventilation and measures for resource saving <p>Governments can</p> <ul style="list-style-type: none"> promote passive architecture through building codes set standards for building design and construction introduce voluntary building rating schemes facilitate a legal environment, technical assistance, financial support and policy reforms incentivise and enable initiatives such as green roofs, rainwater harvesting <p>Organizations can</p> <ul style="list-style-type: none"> show leadership by internal targets and promoting green office buildings <p>Energy saving behavior/use of ICT/smart sensors/smart metering Organizations can</p> <ul style="list-style-type: none"> build a culture that encourages energy saving behaviour of participants conduct regular energy audits and enhance transparent reporting enforce regulations to set criteria for energy services such as lighting, space heating/cooling <p>Consumers can</p> <ul style="list-style-type: none"> install smart-meters or devices that provide consumption information invest in efficient/long lasting appliances 	<p>Heat pumps, district heating and cooling Local governments can</p> <ul style="list-style-type: none"> introduce technologies as part of strategic planning enable secure financing engage with the private sector establish a dynamic policy framework that can be adapted to local conditions while reducing investor risk <p>Switch from informal cooking fuels to cleaner fuels (NG) governments can</p> <ul style="list-style-type: none"> implement concrete, implementable domestic policies and plans set targets and effective monitoring mechanisms <p>Development agencies</p> <ul style="list-style-type: none"> can invest in the sector and channelize significant private investments 	<p>Solar water heaters city governments can</p> <ul style="list-style-type: none"> mandate this in existing building codes/urban guidelines incentivise solar water heaters through subsidies <p>Companies</p> <ul style="list-style-type: none"> can increase awareness and transparency regarding the benefits of solar water heaters <p>Distributed renewable generation governments/private sector</p> <ul style="list-style-type: none"> set local renewable energy targets can incentivize infrastructure to enhance uptake of distributed energy technologies low interest financing to consumers commit to power purchase agreements feed-in tariffs <p>Shift to low impact options (more efficient appliances, etc) Product developers/designers</p> <ul style="list-style-type: none"> design from a user-centric perspective by understanding user needs more effectively <p>Manufacturers can</p> <ul style="list-style-type: none"> provide information on product design strategies that enhance awareness about the product <p>Consumers can</p> <ul style="list-style-type: none"> make responsible purchase decisions regarding appliances <p>Governments can</p> <ul style="list-style-type: none"> set minimum energy performance standards and labels raise awareness regarding energy efficiency and conservation incentives to promote energy saving appliances <p>Researchers can</p> <ul style="list-style-type: none"> identify opportunities or synergies between implementation of clean energy policies and other goals such as climate change mitigation or development

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References

- Abdessalem T and Labidi E 2016 Economic analysis of the energy-efficient household appliances and the rebound effect *Energy Effici.* **9** 605–20
- Abreu M F, Alves A C and Moreira F 2017 Lean-Green models for eco-efficient and sustainable production *Energy* **137** 846–53
- Acheampong R A and Siiba A 2018 Examining the determinants of utility bicycling using a socio-ecological framework: an exploratory study of the Tamale Metropolis in Northern Ghana *J. Transp. Geogr.* **69** 1–10
- Ahmad S and Puppim de Oliveira J A 2016 Determinants of urban mobility in India: lessons for promoting sustainable and inclusive urban transportation in developing countries *Trans. Policy* **50** 106–14
- Ahmed M R and Karmaker A K 2019 Challenges for electric vehicle adoption in Bangladesh 2019 *International Conference on Electrical, Computer and Communication Engineering (ECCE)* (Piscataway, NJ: IEEE) pp 1–6
- Ahvenniemi H and Häkkinen T 2019 Households' potential to decrease their environmental impacts: a cost-efficiency analysis of carbon saving measures *Int. J. Energy Sect. Manage.* **14** 193–212
- Aittasalo M, Tiilikainen J, Tokola K, Seimelä T, Sarjala S M, Metsäpuro P and Vaismaa K 2017 Socio-ecological intervention to promote active commuting to work: protocol and baseline findings of a cluster randomized controlled trial in Finland *Int. J. Environ. Res. Public Health* **14** 1257
- Alawneh R, Mohamed Ghazali F E, Ali H and Asif M 2018 Assessing the contribution of water and energy efficiency in green buildings to achieve United Nations sustainable development goals in Jordan *Build. Environ.* **146** 119–32
- Arora M, Kaushik N, Jain T, Kaur B, Vashisth P, Khosla K and Bhatia S 2016 HumSafar: an android app enabling a safer way to travel 2016 *Fourth Int. Conf. on Parallel, Distributed and Grid Computing (PDGC)* (December 2016) (IEEE) pp 656–61
- Ascione F 2017 Energy conservation and renewable technologies for buildings to face the impact of the climate change and minimize the use of cooling *Sol. Energy* **154** 34–100
- Ashraf N, Comyns B, Arain G A and Bhatti Z A 2018 The roles of network embeddedness, market incentives, and slack resources in the adoption of clean technologies by firms in developing countries *Clim. Policy* **19** 556–70
- Aymeric G and François S 2017 Case study for Chile: the electric vehicle penetration in Chile *Electric Vehicles: Prospects and Challenges* (Amsterdam: Elsevier) pp 245–85
- Bai C, Shah P, Zhu Q and Sarkis J 2018 Green product deletion decisions: an integrated sustainable production and consumption approach *Ind. Manage. Data Syst.* **118** 349–3489
- Bajželj B, Richards K, Allwood J, Smith P, Dennis J, Curmi E and Gilligan C 2014 Importance of food-demand management for climate mitigation *Nat. Clim. Change* **4** 924–9
- Balaban O and de Oliveira J A 2017 Sustainable buildings for healthier cities: assessing the co-benefits of green buildings in Japan *J. Clean. Prod.* **163** S68–S78
- Batchelor S, Brown E, Scott N and Leary J 2019 Two birds, one stone—reframing cooking energy policies in Africa and Asia *Energies* **12** 1591
- Becker N and Carmi N 2019 Changing trip behavior in a higher education institution: the role of parking fees *Int. J. Sustain. Transp.* **13** 268–77
- Behnassi M, Boussaid M and Gopichandran R 2014 Achieving food security in a changing climate: the potential of climate-smart agriculture *Environmental Cost and Face of Agriculture in the Gulf Cooperation Council Countries* (Berlin: Springer) pp 27–42
- Bellantuono N, Carbonara N and Pontrandolfo P 2017 The organization of eco-industrial parks and their sustainable practices *J. Clean. Prod.* **161** 362–75
- Bertarelli S and Lodi C 2019 Heterogeneous firms, exports and pigouvian pollution tax: does the abatement technology matter? *J. Clean. Prod.* **228** 1099–110
- Bigerna S, Micheli S and Polinori P 2019 Willingness to pay for electric boats in a protected area in Italy: a sustainable tourism perspective *J. Clean. Prod.* **224** 603–13
- Bigerna S and Polinori P 2015 Willingness to pay and public acceptance for hydrogen buses: a case study of Perugia *Sustainability* **7** 13270–89
- Bonasif J 2017 Urban transportation conditions from the metropolitan area of Kuala Lumpur that will impact and endanger Putrajaya's sustainability plan *Environmental Engineering. Proc. of the Int. Conf. on Environmental Engineering (ICEE)* vol 10 (Vilnius Gediminas Technical University, Department of Construction Economics & Property) pp 1–8
- Boßmann T, Elsland R, Klingler A L, Catenazzi G and Jakob M 2015 Assessing the optimal use of electric heating systems for integrating renewable energy sources *Energy Procedia* **83** 130–9
- Bramer W M et al 2017 Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study *Syst. Rev.* **6** 245
- Campbell B, Thornton P, Zougmore R, Asten P V and Lipper L 2014 Sustainable intensification: what is its role in climate smart agriculture? *Curr. Opin. Environ. Sustain.* **8** 39–43
- Carroll P, Caulfield B and Ahern A 2019 Modelling the potential benefits of increased active travel *Trans. Policy* **79** 82–92
- Casado-Mansilla D, Moschos I, Kamara-Esteban O, Tsolakis A C, Borges C E, Krinidis S and López-de-ípiña D 2018 A human-centric & context-aware IoT framework for enhancing energy efficiency in buildings of public use *IEEE Access* **6** 31444–56
- Ceccato R and Diana M 2018 Substitution and complementarity patterns between traditional transport means and car sharing: a person and trip level analysis *Transportation (2018)* **1**–18
- Cetin K S and Kallus C 2016 Data-driven methodology for energy and peak load reduction of residential HVAC systems *Procedia Eng.* **145** 852–9
- Chardon C M 2019 The contradictions of bike-share benefits, purposes and outcomes *Transp. Res. A* **121** 401–19
- Cheah S K A, Yeow P H P, Nair S R and Tan F B 2018 Behavioural modification framework to address wastage in household electricity consumption *Ergonomics* **61** 627–43
- Creutzig F, Roy J, Lamb W F, Azevedo I M, Bruin W B and Weber E U 2018 Towards demand-side solutions for mitigating climate change *Nat. Clim. Change* **8** 260
- Darko A, Chan A P C, Gyamfi S, Olanipekun A O, He B-J and Yu Y 2017 Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective *Build. Environ.* **125** 206–15
- Dhar S, Pathak M and Shukla P R 2020 Transformation of India's steel and cement industry in a sustainable 1.5 °C world *Energy Policy* **137**
- Doorley R, Pakrashi V and Ghosh B 2015 Quantification of the potential health and environmental impacts of active travel in Dublin, Ireland *Transp. Res. Rec.* **2531** 129–36

- Dubash N K, Raghunathan D, Sant G and Sreenivas A 2013 Indian climate change policy: exploring a co-benefits based approach *Econ. Polit. Wkly.* **48** 47–61
- EAT-Lancet Commission 2019 Food in the anthropocene: the EAT-Lancet commission on healthy diets from sustainable food systems (available at: www.thelancet.com/commissions/EAT)
- Elasha B O 2010 Mapping of climate change threats and human development impacts in the Arab region *UNDP Arab Development Report—Research Paper Series, UNDP Regional Bureau for the Arab States*
- ElMassah S 2018 Industrial symbiosis within eco-industrial parks: sustainable development for Borg El-Arab in Egypt *Bus. Strategy Environ.* **27** 884–92
- Fabi V, Barthelmes V M, Schweiker M and Corgnati S P 2017 Insights into the effects of occupant behaviour lifestyles and building automation on building energy use *Energy Procedia* **140** 48–56
- Fenton P 2017 Sustainable mobility in the low carbon city: digging up the highway in Odense, Denmark *Sustain. Cities Soc.* **29** 203–10
- Fischedick M, Roy J, Abdel-Aziz A, Acquaye A, Allwood J, Ceron J-P and Tanaka K 2014 *Industry Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press) pp 739–810 (<https://www.ipcc.ch/report/ar5/wg3/>)
- Fraccascia L 2019 The impact of technical and economic disruptions in industrial symbiosis relationships: an enterprise input-output approach *Int. J. Prod. Econ.* **213** 161–74
- Franquesa-Soler M and Sandoval-Rivera J C A 2019 Mentoring program to achieve SDGs in local contexts: a case study in communities from Southern Mexico *Sustainability* **12** 109–14
- Ge J, Weng J T, Zhao K, Gui X C, Li P and Lin M M 2018 The development of green building in China and an analysis of the corresponding incremental cost: a case study of Zhejiang Province *Lowland Technol. Int.* **20** 321–30
- Gilderbloom J, Grooms W, Mog J and Meares W 2016 The green dividend of urban biking? Evidence of improved community and sustainable development *Local Environ.* **21** 991–1008
- Goldman D, Ayalon O, Baum D and Weiss B 2018 Influence of 'green school certification' on students' environmental literacy and adoption of sustainable practice by schools *J. Clean. Prod.* **183** 1300–13
- Gota S, Huizenga C, Peet K, Medimorec N and Bakker S 2019 Decarbonising transport to achieve Paris Agreement targets *Energy Effici.* **12** 363–86
- Guo Y, Xia X, Zhang S and Zhang D 2018 Environmental regulation, government R&D funding and green technology innovation: evidence from China provincial data *Sustainability* **10** 940
- Hens L, Block C, Cabello-Eras J, Sagastume-Gutierrez A, Garcia-Lorenzo D, Chamorro C and Vandecasteele C 2018 On the evolution of 'cleaner production' as a concept and a practice *J. Clean. Prod.* **172** 3323–33
- Hildén E, Ojala J and Väänänen K 2016 User needs and expectations for future traveling services in buses *Proc. of the 9th Nordic Conf. on Human-Computer Interaction (October 2016)* pp 1–6
- HIMAP 2019 *Exploring Futures of the Hindu Kush Himalaya: Scenarios and Pathways* (Berlin: Springer)
- Ho C, Mulley C, Tsai C H, Ison S and Wiblin S 2017 Area-wide travel plans—targeting strategies for greater participation in green travel initiatives: a case study of Rouse Hill Town Centre, NSW Australia *Transportation* **44** 325–52
- Hoegh-Guldberg O et al 2019 *The Ocean as a Solution to Climate Change: Five Opportunities for Action. Report* (Washington, DC: World Resources Institute) (available at: www.oceanpanel.org/climate)
- Holmes H 2018 New spaces, ordinary practices: circulating and sharing within diverse economies of provisioning *Geoforum* **88** 138–47
- Hu M 2017 Assessment of effective energy retrofit strategies and related impact on indoor environmental quality: a case study of an elementary school in the State of Maryland *J. Green Build.* **12** 38–55
- Huang M, Wang Z and Chen T 2019 Analysis on the theory and practice of industrial symbiosis based on bibliometrics and social network analysis *J. Clean. Prod.* **213** 956–67
- IPBES 2016 *Summary for Policymakers of the Methodological Assessment of Scenarios and Models of Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services)
- IPCC 2018 Summary for policy makers *Global Warming of 1.5 °C*
- IPCC 2019 Climate change and land: IPCC special report on climate change, desertification, land degradation, sustainable land management, food security and greenhouse gas fluxes in terrestrial ecosystems (IPCC)
- Javied T, Rackow T and Franke J 2015 Implementing energy management system to increase energy efficiency in manufacturing companies *Procedia CIRP* **26** 156–61
- Jensen R H, Kjeldskov J and Skov M B 2018 Assisted shifting of electricity use: a long-term study of managing residential heating *ACM Trans. Comput.-Hum. Interact.* **25**
- Jin M, Tang R, Ji Y, Liu F, Gao L and Huisingh D 2017 Impact of advanced manufacturing on sustainability: an overview of the special volume on advanced manufacturing for sustainability and low fossil carbon emissions *J. Clean. Prod.* **161** 69–74
- Khan S, Maoh H, Lee C and Anderson W 2016 Toward sustainable urban mobility: investigating nonwork travel behavior in a sprawled Canadian city *Int. J. Sustain. Transp.* **10** 321–31
- Kim J, Lee S and Kim K S 2017 A study on the activation plan of electric taxi in Seoul *J. Clean. Prod.* **146** 83–93
- Konrad W 2015 Making sense of sustainability, energy policies and citizens' related domestic behaviour. A case study in Germany *PapRevSoc.* **100** 453
- Lamb W F, Callaghan M W, Creutzig F, Khosla R and Minx J C 2018 The literature landscape on 1.5 °C climate change and cities *Curr. Opin. Environ. Sustain.* **30** 26–34
- Langbroek J H, Franklin J P and Susilo Y O 2017 Electric vehicle users and their travel patterns in Greater Stockholm *Transp. Res. D* **52** 98–111
- Langlois M, Van Lierop D, Wasfi R A and El-Geneidy A M 2015 Chasing sustainability do new transit-oriented development residents adopt more sustainable modes of transportation? *Transp. Res. Rec.* **2531** 83–92
- Lelono A D, Herdiansyah H, Darmajanti L, Soesilo T E B, Hasibuan H S and Dwipayana 2018 Pro-environmental behaviour in travel mode choice of graduate students: case study in Jakarta *E3S Web of Conf.* **09001** 65
- Lichtenwoehr P, Erker S, Zach F and Stoeglehner G 2019 Future compatibility of district heating in urban areas—a case study analysis in the context of integrated spatial and energy planning *Energy, Sustain. Soc.* **9** 1–12
- Lin X, Wells P and Sovacool B K 2018 The death of a transport regime? The future of electric bicycles and transportation pathways for sustainable mobility in China *Technol. Forecast. Soc. Change* **132** 255–67
- Lipper L, Thornton P, Campbell B M, Baedeker T, Braimoh A, Bwalya M and Torquebiau E F 2014 Climate-smart agriculture for food security *Nat. Clim. Change* **4** 1068–107
- Liu H and Lin B 2016 Incorporating energy rebound effect in technological advancement and green building construction: a case study of China *Energy Build.* **129** 150–61
- Liu J, Zeng P and Li D 2015 A transmitting algorithm based on traffic redirecting in industrial energy-efficient multi-hop wireless networks *2015 IEEE Int. Conf. on Cyber Technology*

- in *Automation, Control and Intelligent Systems, IEEE-CYBER 2015* pp 1017–22
- Liu L 2018 IoT and a sustainable city *Energy Procedia* **153** 342–6
- Liu Z Y, Li C, Fang X Y and Guo Y B 2018 Energy consumption in additive manufacturing of metal parts *Procedia Manuf.* **26** 834–45
- Long T, Blok V and Coninx I 2016 Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy *J. Clean. Prod.* **112** 9–21
- Lourenço P, Pinheiro M D and Heitor T 2019 Light use patterns in Portuguese school buildings: user comfort perception, behaviour and impacts on energy consumption *J. Clean. Prod.* **228** 990–1010
- Ma Y, Lan J, Thornton T, Mangalagiu D and Zhu D 2018b Challenges of collaborative governance in the sharing economy: the case of free-floating bike sharing in Shanghai *J. Clean. Prod.* **197** 356–65
- Ma Y, Rong K, Mangalagiu D, Thornton T F and Zhu D 2018a Co-evolution between urban sustainability and business ecosystem innovation: evidence from the sharing mobility sector in Shanghai *J. Clean. Prod.* **188** 942–53
- Macmillan A, Smith M, Witten K, Woodward A, Hosking J, Wild K and Field A 2020 Suburb-level changes for active transport to meet the SDGs: causal theory and a New Zealand case study *Sci. Total Environ.* **714** 136678
- Malodia S and Singla H 2016 A study of carpooling behaviour using a stated preference web survey in selected cities of India *Transp. Plann. Technol.* **39** 538–50
- Mastrucci A, Byers E, Pachauri S and Rao N D 2019 Improving the SDG energy poverty targets: residential cooling needs in the Global South *Energy Build.* **186** 405–15
- Matic D, Roset Calzada J and Todorovic M S 2016 Renewable energy sources-integrated refurbishment approach for low-rise residential prefabricated building in Belgrade, Serbia *Indoor Built Environ.* **25** 1016–23
- Matinaro V, Liu Y and Poesche J 2019 Extracting key factors for sustainable development of enterprises: case study of SMEs in Taiwan *J. Clean. Prod.* **209** 1152–69
- Mbakwe S 2016 Design and application of a photovoltaic powered domestic solar water heating system in Regina, SK, Canada *2016 IEEE Electrical Power and Energy Conf. (EPEC) (October 2016)* (IEEE) pp 1–8
- Mehdizadeh M, Nordfjaern T and Mamdoohi A R 2019 Environmental norms and sustainable transport mode choice on children's school travels: the norm-activation theory *Int. J. Sustain. Transp.* **0** 1–13
- Menato S, Carimati S, Montini E, Innocenti P, Canetta L and Sorlini M 2017 Challenges for the adoption of industrial symbiosis approaches within industrial agglomerations *Int. Conf. on Engineering, Technology and Innovation (ICE/ITMC)* (IEEE) pp 1293–9
- Meskers C, Caffarey M and Camp M V 2019 Circular cities, E-mobility and the metals industry—a world in transition *Rewas 2019 (The Minerals, Metals & Materials Series)* (Berlin: Springer) pp 313–8
- Mir H M, Behrang K, Isaai M T and Nejat P 2016 The impact of outcome framing and psychological distance of air pollution consequences on transportation mode choice *Transp. Res. D* **46** 328–38
- Mitra R and Nash S 2019 Can the built environment explain gender gap in cycling? An exploration of university students' travel behavior in Toronto, Canada *Int. J. Sustain. Transp.* **13** 138–47
- Mizobuchi K and Takeuchi K 2016 Replacement or additional purchase: the impact of energy-efficient appliances on household electricity saving under public pressures *Energy Policy* **93** 137–48
- Mozos-Blanco M Á, Pozo-Menéndez E, Arce-Ruiz R and Baucells-Aletà N 2018 The way to sustainable mobility. A comparative analysis of sustainable mobility plans in Spain *Trans. Policy* **72** 45–54
- Muller M F, Esmanioto F, Huber N, Loures E R and Canciglieri Junior O 2019 A systematic literature review of interoperability in the green building information modeling lifecycle *J. Clean. Prod.* **223** 397–412
- Nascimento D L, Alencastro V, Quelhas O L, Caiado R G, Garza-Reyes J A, Rocha-Lona L and Tortorella G 2019 Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context: a business model proposal *J. Manuf. Technol. Manage.* **30** 607–27
- Pearce D W and Turner R K 1990 *Economics of Natural Resources and the Environment* (Baltimore, MD: Johns Hopkins University Press)
- Permatasari C I, Sutopo W and Hisjam M 2018 Sales forecasting newspaper with ARIMA: a case study *AIP Conf. Proc.* **1931** 030017
- Pigosso D C, Schmiegelow A and Andersen M M 2018 Measuring the readiness of SMEs for eco-innovation and industrial symbiosis: development of a screening tool *Sustainability* **10** 2861
- Pillay S and Buys P 2016 Investigating the impact of carbon tax on socially responsible corporate governance: the case of South African motor vehicle manufacturers *Corp. Ownersh. Control* **12** 128–34
- Piramuthu O B and Zhou W 2016 Bicycle sharing, social media, and environmental sustainability *Proc. Annual Hawaii Int. Conf. on System Sciences (March 2016)* pp 2078–83
- Poblete-Cazenave M and Pachauri S 2018 A structural model of cooking fuel choices in developing countries *Energy Econ.* **75** 449–63
- Prasad P and Maitra B 2019 Identifying areas of interventions for improvement of shared modes for school trips *Transp. Res. A* **121** 122–35
- Ramezani S, Pizzo B and Deakin E 2018 Determinants of sustainable mode choice in different socio-cultural contexts: a comparison of Rome and San Francisco *Int. J. Sustain. Transp.* **12** 648–64
- Rarasati A D and Iskandar T R 2017 Integrated sustainability for transportation infrastructure development in Indonesia: a case study of Karawang region *MATEC Web of Conf. (EDP Sciences)* vol 138 p 07004
- Reza F, Wilde W J and Izevbehai B 2018 Sustainability of using recycled concrete aggregates as coarse aggregate in concrete pavements *Transp. Res. Rec.* **2672** 99–108
- Romero-Pérez C K, Rodríguez-Muñoz N A, Alpuche-Cruz M G and Martín-Domínguez I R 2017 Preliminary study of the condition of social housing in the city of Durango, México *9th Int. Conf. on Sustainability and Energy in Buildings, SEB 2017* vol 134, ed J Littlewood and R J Howlett (Elsevier) pp 29–39
- Rosenthal J, Quinn A, Grieshop A P, Pillarissetti A and Glass R I 2018 Clean cooking and the SDGs: integrated analytical approaches to guide energy interventions for health and environment goals *Energy Sustain. Dev.* **42** 152–9
- Roy J, Chakravarty D, Dasgupta S, Chakraborty D, Pal S and Ghosh D 2018b Where is the hope? Blending modern urban lifestyle with cultural practices in India *Curr. Opin. Environ. Sustain.* **31** 96–103
- Roy J et al 2018a Sustainable development, poverty eradication and reducing inequalities *Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* eds V Masson-Delmotte et al (Cambridge: Cambridge University Press) pp 445–538 (https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter_5_High_Res.pdf) accepted
- Rudolph C 2016 How may incentives for electric cars affect purchase decisions? *Trans. Policy* **52** 113–20
- Safaei A, Freire F and Antunes C H 2015 A life cycle multi-objective economic and environmental assessment of

- distributed generation in buildings *Energy Convers. Manage.* **97** 420–7
- Safarzadeh S and Rasti-Barzoki M 2019 A game theoretic approach for pricing policies in a duopolistic supply chain considering energy productivity, industrial rebound effect, and government policies *Energy* **167** 92–105
- Salpakari J and Lund P 2016 Optimal and rule-based control strategies for energy flexibility in buildings with PV *Appl. Energy* **161** 425–36
- Schneider R J and Willman J L 2019 Move closer and get active: how to make urban university commutes more satisfying *Transp. Res. F* **60** 462–73
- Schoenau M and Müller M 2017 What affects our urban travel behavior? A GPS-based evaluation of internal and external determinants of sustainable mobility in Stuttgart (Germany) *Transp. Res. F* **48** 61–73
- Shahbazi S, Jönsson C, Wiktorsson M, Kurdve M and Bjelkemyr M 2018 Material efficiency measurements in manufacturing: Swedish case studies *J. Clean. Prod.* **181** 17–32
- Shen Q, Xu S and Lin J 2018 Effects of bus transit-oriented development (BTOD) on single-family property value in Seattle metropolitan area *Urban Stud.* **55** 2960–79
- Shmelev S E and Shmeleva I A 2018 Global urban sustainability assessment: a multidimensional approach *Sustain. Dev.* **26** 904–20
- Sjöman M, Ringenson T and Kramers A 2020 Exploring everyday mobility in a living lab based on economic interventions *Eur. Transp. Res. Rev.* **12** 5
- Skayannis P, Goudas M, Crone D, Cavill N, Kahlmeier S and Mitsiadi V 2019 Health related benefits of non-motorised transport: an application of the health economic assessment tool of the world health organisation to the case of Trikala, Greece *The 4th Conf. on Sustainable Urban Mobility* (Berlin: Springer) pp 789–96
- Sodagar B and Starkey D 2016 The monitored performance of four social houses certified to the code for sustainable homes level 5 *Energy Build.* **110** 245–56
- Some S 2020 Exploring mitigation interventions and SDGs link: Evidences from Indian agriculture Exploring mitigation interventions and SDGs link: Evidences from Indian agriculture Paradigms, Models, Scenarios and Practices for strong sustainability ed A Diemer Oeconomia (Clermont-Ferrand: Imprimerie Print Conseil) pp 339–56 (https://www.researchgate.net/publication/341164905_Paradigms_Models_Scenarios_and_Practices_for_strong_sustainability) English
- Soo V K, Peeters J, Paraskevas D, Compston P, Doolan M and Duflou J R 2018 Sustainable aluminium recycling of end-of-life products: a joining techniques perspective *J. Clean. Prod.* **178** 119–32
- South Point School 2019 *School Transport* (available at: www.southpoint.edu.in/school-transport/)
- Sovacool B K, Axsen J and Sorrell S 2018 Promoting novelty, rigor, and style in energy social science: towards codes of practice for appropriate methods and research design *Energy Res. Social Sci.* **45** 12–42
- Sovacool B K, Kester J and Heida V 2019 Cars and kids: childhood perceptions of electric vehicles and sustainable transport in Denmark and the Netherlands *Technol Forecast Soc. Change* **144** 182–92
- sRide 2019 *sRide-Trusted Social Carpooling App* (available at: <https://sride.co/>)
- Steinemann A, Wargocki P and Rismanchi B 2017 Ten questions concerning green buildings and indoor air quality *Build. Environ.* **112** 351–8
- Stojanovski T 2019 Urban form and mobility choices: informing about sustainable travel alternatives, carbon emissions and energy use from transportation in Swedish neighbourhoods *Sustainability* **11** 548
- Su Y W 2019 Residential electricity demand in Taiwan: consumption behavior and rebound effect *Energy Policy* **124** 36–45
- Teng J, Mu X, Wang W, Xu C and Liu W 2019 Strategies for sustainable development of green buildings *Sustain. Cities Soc.* **44** 215–26
- Trinh T A and Linh L T 2018 Investigating proenvironmental behavior: the case of commuting mode choice *IOP Conf. Ser.: Earth Environ. Sci.* **143** 012067
- Tu J C and Yang C 2019 Key factors influencing consumers' purchase of electric vehicles *Sustainability* **11** 3863
- UNDP 2016 Risk governance: building blocks for resilient development in the Pacific *Policy Brief* (Suva, Fiji: United Nations Development Programme (UNDP) and Pacific Risk Resilience Programme (PRRP)) (<https://www.nab.vu/sites/default/files/documents/PRRP%20Risk%20Governance-Policy%20Brief.pdf>)
- UNEP 2017 *The Emissions Gap Report 2017* (Nairobi, Kenya: United Nations Environment Programme (UNEP)) (https://wedocs.unep.org/bitstream/handle/20.500.11822/22070/EGR_2017.pdf?sequence=1&isAllowed=y)
- Ürge-Vorsatz D, Rosenzweig C, Dawson R, Rodriguez R, Bai X, Barau A S and Dhakal S 2018 Locking in positive climate responses in cities *Nat. Clim. Change* **8** 174
- Useche S A, Montoro L, Sanmartin J and Alonso F 2019 Healthy but risky: a descriptive study on cyclists' encouraging and discouraging factors for using bicycles, habits and safety outcomes *Transp. Res. F* **62** 587–98
- van der Meulen S H 2019 Costs and benefits of green roof types for cities and building owners *J. Sustain. Dev. Energy Water Environ. Syst.* **7** 57–71
- Vanzella A, Zat G, Scherer H V, Alves L L L and Fraga D J 2018 Move: test case for electric carsharing at Itaipua *IEEE Conf. on Intelligent Transportation Systems, Proc., ITSC (November 2018)* pp 1562–7
- Walzberg J, Dandres T, Merveille N, Cheriet M and Samson R 2019 Assessing behavioural change with agent-based life cycle assessment: application to smart homes *Renew. Sustain. Energy Rev.* **111** 365–76
- Wang H, Liu X, Apostolidis P and Scarpas T 2018a Review of warm mix rubberized asphalt concrete: towards a sustainable paving technology *J. Clean. Prod.* **177** 302–14
- Wang X, Wu Q, Majeed S and Sun D 2018b Fujian's industrial eco-efficiency: evaluation based on SBM and the empirical analysis of influencing factors *Sustainability* **10** 3333
- Wethayavorn P and Sukwattanakorn N 2019 Problems and barriers affecting sustainable commuting: case study of people's daily commute to Kasetsart University, Bangkok, Thailand *IOP Conf. Ser.: Earth Environ. Sci.* **329** 012011
- Whittle C, Whitmarsh L, Hagger P, Morgan P and Parkhurst G 2019 User decision-making in transitions to electrified, autonomous, shared or reduced mobility *Transp. Res. D* **71** 302–19
- Withanage C, Hölltä-Otto K, Otto K and Wood K 2016 Design for sustainable use of appliances: a framework based on user behavior observations *J. Mech. Des. Trans. ASME* **138** 101102
- Wunsch M, Stibe A, Millonig A, Seer S, Chin R C and Schechtner K 2016 Gamification and social dynamics: insights from a corporate cycling campaign *Int. Conf. on Distributed, Ambient, and Pervasive Interactions* (Berlin: Springer) pp 494–503
- Yang W H, Wong R C P and Szeto W Y 2018 Modeling the acceptance of taxi owners and drivers to operate premium electric taxis: policy insights into improving taxi service quality and reducing air pollution *Transp. Res. A* **118** 581–93
- Yang Y, Chen L, Jia F and Xu Z 2019 Complementarity of circular economy practices: an empirical analysis of Chinese manufacturers *Int. J. Prod. Res.* **57** 6369–84
- Zaid S M, Kiani Rad A and Zainon N 2017 Are green offices better than conventional?: measuring operational energy consumption and carbon impact of green office in Malaysia *Facilities* **35** 622–37
- Zhang W, Gu F, Dai F, Gu X, Yue F and Bao B 2016 Decision framework for feasibility analysis of introducing the steam

turbine unit to recover industrial waste heat based on economic and environmental assessments *J. Clean. Prod.* [137](#) 1491–502

Zhang X, Bai X and Shang J 2018 Is subsidized electric vehicles adoption sustainable: consumers' perceptions and

motivation toward incentive policies, environmental benefits, and risks *J. Clean. Prod.* [192](#) 71–79

Zhao X, Zuo J, Wu G and Huang C 2019 A bibliometric review of green building research 2000–2016 *Archit. Sci. Rev.* [62](#) 74–88