Journal of Cleaner Production 347 (2022) 131256

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Socioeconomics determinants of household carbon footprint in Iskandar Malaysia

Irina Safitri Zen [a], M. Salim Uddin [b,d], Abul Quasem Al-Amin [b,c,*], Mohammad Rafee Bin Majid [e], Abdulaziz I. Almulhim [f], Brent Doberstein [b]

[a] Department of Urban Regional Planning (URP), Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia (IIUM), Malaysia
[b] Department of Geography and Environmental Management, University of Waterloo, ON, Canada
[c] Department of Development Studies, Daffodil International University, Bangladesh
[d] Centre for Asian Climate and Environmental Policy Studies (CACEPS), ON, Canada
[e] Fakulti Alam Bina and Ukur, Perancangan Bandar and Wilayah, Fakulti Alam Bina Universiti Teknologi Malaysia Skudai, Malaysia
[f] Department of Urban and Regional Planning, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, P. O. Box 1982, Dammam, 31451, Saudi Arabia

ARTICLE INFO

Handling Editor: Jing Meng

Keywords:
Carbon footprint
Climate change
Household lifestyle
Energy consumption
Environmental awareness

ABSTRACT

Understanding the complex links between socioeconomic variables and carbon emissions can reveal household spending and lifestyle patterns. This study oversees those issues and examines consumption patterns and their related variables such as climate change understanding, attitudes, and knowledge, in order to better comprehend the complicated linkages. This study revealed that eight socioeconomic elements influence a household's carbon footprint: (i) household income ($\beta = 0.476$, $p < 0.05$), (ii) green attitudes ($\beta = -0.196$, $p < 0.05$), (iii) residential space ($\beta = 0.157$, $p < 0.05$), (iv), education levels ($\beta = 0.131$, $p < 0.05$), (v) household's tenure status by ownership ($\beta = 0.130$, $p < 0.05$), (vi) household's age ($\beta = 0.112$, $p < 0.05$), (vii) size of household ($\beta = 0.101$, $p < 0.05$), and, (viii) female-headed household ($\beta = -0.077$, $p < 0.05$). Approximately 83.6% of respondents are mindful of climate change, but only 2.6% correctly define it as a long-term shift in weather patterns. The study found that 82% of households are willing to change their consumption habits and lifestyle to reduce their household's carbon footprint. In order to achieve a low carbon society, our research advocate a multipronged approach and policy action is crucial based on the results. Further, robust climate change educational and awareness programmes is decisive at the multilevel and scale in Malaysia to achieve its carbon emissions reduction target by 2050.

1. Introduction

Carbon footprints at the household level are unequally distributed between the rich and the poor, and are heavily influenced by a household's socio-economic position within society, which translates into significant differences in household size and consumption patterns. Household member involvement in pursuing a low carbon lifestyle in their daily activities is crucial to understanding the link between the global climate crisis and mitigating greenhouse gas emissions (Baltruszewicz et al., 2021; Liu et al., 2020; Sköld et al., 2018). Households account for up to 72% of global greenhouse gas emissions if all household consumption (both direct and indirect) is included (Sköld et al., 2018; Ivanova et al., 2017). Households account for more than 80% of carbon emissions in the United States, and more than 70% in UK and India (Baiocchi et al., 2010; Bin and Dowlatabadi, 2005).

Malaysia's overall carbon emissions in 2019 were 250.09 million tonnes (Ritchie and Roser, 2020), which is close to the forecast of 285.73 million tonnes in 2020 if no mitigation measures are taken by the Malaysian government (Safaai et al., 2011; Sarkar et al., 2019). It is a more than threefold increase of 320% from the total 88.97 million tonnes of carbon emissions in 2000. Carbon emissions in Malaysia are divided into the following: 49.6% from electricity and heat production, 24.2% from manufacturing industries and construction, 23.3% from transportation, and 2.9% from other sources, with the residential sector

* Corresponding author. Department of Geography and Environmental Management, University of Waterloo, ON, Canada.
E-mail addresses: irinazen@iium.edu.my (I.S. Zen), msalim.uddin@uwaterloo.ca (M.S. Uddin), al.amin@caceps.ca (A.Q. Al-Amin), rafee@utm.my (M.R.B. Majid), aialmulhim@iau.edu.sa (A.I. Almulhim), bdoberst@uwaterloo.ca (B. Doberstein).

https://doi.org/10.1016/j.jclepro.2022.131256
Received 23 May 2021; Received in revised form 27 January 2022; Accepted 6 March 2022
Available online 12 March 2022

accounting for 37.3% emissions (i.e., 19.8% for electricity and heat production and 17.4% for transportation). In the residential sector, the use of energy to power equipment and electrical appliances such as refrigerators contributed the most to pollution (Nor et al., 2016).

According to household spending studies, food accounts for around 31% of a Malaysian household's monthly expenditures, whether in restaurants or at home (Zen et al., 2021; Abdullah Chik et al., 2013; Household Expenditure Survey, 2005). Housing and transportation rank second and third, with 18% and 17% of household expenditures coming from energy consumption and travel resulting from the combustion of fossil fuels by private motor vehicles, respectively. Malaysia's residential electrical energy usage accounts for 16–50% of total energy consumption as compared to other countries (Saidur et al., 2007), so households are considered to be the primary energy consumers in Malaysia, both directly and indirectly.

Unsustainable patterns of consumption and lifestyle from human activities has caused the most significant reasons for increasing carbon emissions globally. Such emissions have caused increasing global mean temperatures, and climate change (UNFCCC, 2015; Parry et al., 2007) is now as stated in section 4 of Agenda 21, is a significant damaging factor of the global environment (United Nation General Assembly, 1992). Since the 1992 World Summit in Rio, addressing carbon emissions has been elevated to a top priority, however slow progress has been made in the context of transitioning to a sustainable consumption and lifestyle (Alicia et al., 2012; Thøgersen, 2005). Furthermore, the Paris Agreement 2015 (UNFCCC, 2015) set out international climate goals, and according to consensus estimates by the Intergovernmental Panel on Climate Change (IPCC), by 2100, anthropogenic greenhouse gas emissions should be "net zero" (Pachauri and Mayer, 2015). Hence, it is crucial to establish a link between '*household lifestyles*'[1] and the carbon emitted from '*household daily life*'.

Household carbon footprints have both direct and indirect implications for national and international carbon contributions to the atmosphere (Serino and Klasen, 2015). Household carbon emission studies elucidate the behavioural characteristics, personal lifestyles and differences in consumption patterns of families that can influence the success of carbon mitigation policies at the national level (Levay et al., 2021; Zen et al., 2021; Lee et al., 2021). Researchers have examined the socioeconomic determinants related to consumption patterns and carbon emissions from household daily activity, for example, Wiedenhofer et al. (2017) found that a household's carbon footprint is unequally distributed among the rich and poor due to differences in the scale and patterns of consumption, documenting that, in China in 2012, the very rich 5% of urban populations produces 19% of the total carbon footprint from household consumption or 6.4 tCO_2/cap. In a similar vein, Lee et al. (2021) calculated and compared household carbon footprints in India based on economic, cultural and demographic factors, found that high expenditure households emit seven times more carbon than low-income households (i.e. those living on <$1.90 USD/day). Such research underpins the need to differentiate individual household responsibilities for climate change in national and global climate policy.

Researchers have also quantified the relationship between the carbon footprint of household consumption and socio-economic household characteristics. For example, in Belgian households, income and household size are the most important determinants of household consumption-related emissions, and the intensity of emission is higher for high-income households than the lower income (Levay et al., 2021). Relevant findings were also documented in other countries such as China (Wang et al., 2013), India (Grunewald et al., 2012), UK (Baiocchi et al., 2010), Philippines (Serino and Klasen, 2015), Denmark (Heinonen and Junnila, 2011), and Malaysia (Abdullah Chik et al., 2013). Based on this backdrop, it is important to examine this relationship, especially by isolating the determinants that can unravel the complex interrelated problem of carbon emissions and household consumption and lifestyles.

Malaysia is ranked as the second highest emitter of carbon emissions per capita in Southeast Asia after Singapore, and is committed to reducing the emission intensity of its gross domestic product (GDP) by up to 45% by 2030 from the baseline 2005 data (Farabi et al., 2019). Malaysia's National Climate Change policy clearly mentions its strategic thrust stating that the country will "… *institute measures to make development climate-resilient through low carbon economy to enhance global competitiveness and attain environmentally sustainable socio-economic growth*" (Malaysia National Climate Change Policy, 2010, p.6). Existing efforts towards the development of a low carbon economy include guidelines for green townships, and rating scales for a nationwide project of low carbon Malaysian cities. Other initiatives include setting up a carbon footprint baseline, and then analysing and promoting a low carbon lifestyle for Putrajaya and Cyberjaya townships, establishing Selangor State (Sarker et al., 2018) as a Green Technology State, and making Melaka City a demonstration site for a Smart Communities project (Zen et al., 2016, 2021). Several country-wide sustainable consumption strategies include the promotion of a government green procurement program, implementation of green facilities and infrastructure such as phasing out the incandescent light bulbs, increasing energy performance labelling for electrical appliances, and promoting the ecolabelling of appliances to stimulate the green market and sustainable production. Those multipronged approaches help households to reduce their carbon emissions and to better understand the socio-economic factors that relate to household consumption and lifestyle. The translation of policy to all levels of government (from national and sub-national to local government) demonstrates multi-level climate governance, national and local collaboration, and wider coverage of programmes that address climate change adaptation and mitigation (Farabi et al., 2019; Zen et al., 2019).

The Malaysian government has initiated rigorous policies, plans, guidelines, initiatives, and project interventions that should stimulate movement toward low carbon development and mitigation of carbon emissions from energy sectors, and this is now being reflected in an increase of environmental awareness at the household level, particularly for energy consumption (Zen et al., 2021; Sarker et al., 2018). An analysis of 30 years energy consumption data from 1970 to 2010 in Malaysia based on the Environment Kuznets Curve (EKC) showed a positive trend of improvement in consumption patterns and efficiency (Begum et al., 2015). The research findings of Begum et al. (2015) also capture an increase in the household income and its better impact on the environment. However, an analysis of the impact of household consumption trends on carbon emissions, which used a hybrid input-output model to look at stratum and expenditure groups per capita, discovered that certain income classes contributed more to consumption than others (Zen et al., 2021; Abdullah Chik et al., 2013). The study suggested increased production of less carbon-intensive products which will help to change consumer behaviour. Hence, green technology innovation will be an important aspect of providing more green products and an overall more conducive environment for consumers to purchase sustainably and to follow a sustainable lifestyle. In this backdrop, it is critical to underscore the determinants of the household carbon footprint, the extend of carbon emissions, measuring the level of awareness and knowledge on climate change, and willingness to change household members lifestyle in Malaysia.

To fill the research gap our study analysed the determinants of Malaysian household carbon footprints to determine the extent to which

[1] It is necessary to find a correlation between 'household lifestyles' and the carbon emitted by 'household daily life,' as these two are connected but not identical. For example, h*ousehold lifestyle* is considered as way of living, and on their other hand, *daily living* considered as daily activities. There are two types of activities of daily living (ADLs): (i) fundamental and (i) instrumental. The fundamental ADLs include personal hygiene or grooming, dressing, toileting, transferring or ambulating, and eating and those are associated with household lifestyle and affects daily life as way of living. Thus, this study assessed the links between the two in order to determine the carbon footprints of households.

these determinants affect household carbon emissions, and measured associated levels of awareness, attitudes and knowledge about climate change and the willingness of participants to change their lifestyle. The research was carried out at the households (n = 420) of residents in Iskandar Malaysia, a sustainable metropolis which has the goal of becoming a low-carbon society by 2050. As a result, our research objectives were twofold: firstly, to identify important lifestyle and consumption factors that affect total carbon footprints at the household level, and secondly, to investigate the consequences of urbanisation on urban and rural inhabitants, especially related to their lifestyle.

With this background, the novelty of this study is noteworthy, hardly any studies have looked at the magnitude of carbon footprints from both urban and rural household consumption in terms of socioeconomic determinants and household lifestyles in emerging economies such as Malaysia. This research determined how urbanisation, urban-rural development, and urban sprawl affect Malaysia's carbon emission pattern. The study compares the differences between rural and urban lifestyles in Iskandar Malaysia, as well as the impact of each group on household carbon footprints, which will aid policymakers and planners in better understanding Iskandar Malaysia's households, and indeed many other Malaysian cities undergoing urban development.

2. Socio-economic determinants of carbon footprint

2.1. Socio-economic determinants at households level

Several socio-economic characteristics, such as high income, household size, and type of residential category are associated with high carbon emissions. One of the most critical lifestyle characteristics is a family's income which typically leads to increased energy consumption and carbon emissions with higher family income (Baltruszewicz et al., 2021; Salo et al., 2021; Jack and Ivanova, 2021; Christis et al., 2019; Sköld et al., 2018). Higher income also provides more options of more comfort, consumption of more carbon intensive goods and services, using cars and recreational activities (Levay et al., 2021; Christis et al., 2019; Moser and Kleinhückelkotten, 2018; Grunewald et al., 2012). Higher energy consumption by higher-income households increase direct and indirect carbon emission than low-income households (Levay et al., 2021; Liu et al., 2020; Feng et al., 2011; Liu et al., 2013). For example, Liu et al. (2020) investigated the impact of income inequality on household carbon emissions in China and found a positive correlation—higher income households emit more carbon. Similarly, Lévay et al. (2021) documented that income and household size are the most important determinants of household consumption-related carbon emissions in Belgian households. Household type also matters-urban households use more diverse and energy intensive home electrical and heating devices than rural households, according to China's household carbon emission survey (Zhang et al., 2017; Tian et al., 2014). By contrast, Ottelin et al. (2019) conducted a comparative study on the impact of the degree of urbanization on income, expenditure and carbon footprints in Europe. They found that carbon footprints are 7% lower in cities than in rural areas when income and household characteristics are controlled.

Lifestyles are changing in a globalized world, and these changes have significant implications for household carbon footprints. Households as the basis for citizen consumption that play a significant role in global environmental challenge like climate change, and to control negative environmental consequences require changes to household daily consumption practices. The determinants of lifestyle and socioeconomic characteristics are critical to be identified at the local level to transit to a low carbon society (Salo et al., 2021; Jack and Ivanova, 2021). This means that "being a competent member of society in our global consumption culture means being able to find our way through the set of consumption practices that make up our everyday lives" (Spaargaren and Oosterveer, 2010, p.1895).

The overall energy use tied to personal lifestyles is affected by consumer behaviours such as personal—transportation, utilities, and residences, which collectively account for 45–55% of total household energy usage in Denmark (Jack and Ivanova, 2021), Belgium (Levay et al., 2021; Salo et al., 2021), China (Zhang et al., 2017), Australia (Lenzen, 1998), France, Netherlands and West Germany (Weber and Perrels, 2000). Researchers have examined the extent to which household members are willing to modify their consumption. Sköld et al. (2018) investigated households' preferences to reduce carbon footprints through lifestyle and consumption changes in four mid-size cities in France, Germany, Norway, and Sweden. Their research documented that most households preferred voluntary actions with moderate lifestyle changes such as changes to food consumption and mobility in order to reduce carbon footprints by 25%–50% by 2030. However, more understanding is needed about the socio-economic factors that influence a household's expenditure patterns, lifestyle, and ultimately, consumption.

A search of the literature revealed that several socio-economic determinants affect consumption patterns and lifestyles, and therefore carbon footprints. Household carbon emissions tend to rise with incomes and fall with education as lifestyles and other values are regulated (Levay et al., 2021; Christis et al., 2019). An exploratory study by Lévay et al. (2021) quantify the relationship between the carbon emission and socioeconomic characteristics of Belgian households and found that income and household size are important determinants of carbon emission. Consequently, another study on socio-economic determinants and carbon emissions in a household in UK (Baiocchi et al., 2010) showed a connection between emissions and size of household, income, using the internet, and education. Similarly, study of household carbon emissions in the UK revealed that the three most important carbon footprint factors are housing (type and size), transportation, and food: each of these factors have significant impacts on consumers' lifestyles and emission patterns (Minx et al., 2009). Increased incomes leads to higher transportation emissions, but lower housing emissions (Dubois et al., 2019; Druckman and Jackson, 2009; Tukker and Jansen, 2006). The total amount of carbon footprint is predicted by determinants such as household size, residence location, and lifestyle (Salo et al., 2021; Lévay et al., 2021; Jack and Ivanova, 2021; Bin and Dowlatabadi, 2005).

Other research on carbon footprints reveals additional relationships with other social variables such as household religion, ethnicity, and gender, and this highlights the need for local and household-level studies. In India, Christian and Muslim households have slightly higher carbon footprints than Hindu households (Grunewald et al., 2012). Similar research found that female-headed households had higher carbon emissions than male-headed households with lower transport emissions (DEFRA, 2008). Another research found that male-headed households produce less home energy, lower indirect carbon emissions, and overall less carbon emissions in India (Büchs and Schnepf, 2013; Grunewald et al., 2012). Malaysia is a culturally diverse nation, with at least three major ethnic groups (Indian, Chinese, and majority Malay), as well as four major religions (Christian, Hindu, Buddhist and Muslim). As a result, it is critical to analyse the lifestyles of these different groups and compare the results to see whether religion or ethnicity and gender play a major role in carbon footprint of households, or whether other factors have greater influence over the carbon footprint.

2.2. Awareness and knowledge of climate change and low carbon lifestyle practices

Concerns and awareness about climate change and its consequences can influence household decision-making towards more climate-friendly practises, leading to progress being made toward a low-carbon society. People who are well-informed and committed to their right to a healthy climate (Levay et al., 2021; Dubois et al., 2019; Haron et al., 2005), and have the capability to recognize and assess the effect of their daily practices on the ecosystem (Degenhardt, 2002a; Haron et al., 2005),

may find these characteristics have a significant impact on their decision-making (Dubois et al., 2019). Information and knowledge are seen in the literature as significant predictors of attitudinal and behavioural change. For example, green attitudes towards the environment are usually associated with lower personal carbon footprints, and lower contributions to global warming (Sarker et al., 2019; Alfredsson, 2002; Bin and Dowlatabadi, 2005). Specific attitudes or motives for specific behaviour are supported by operational knowledge, such as household recycling (Zen et al., 2014, 2021; Zen and Siwar, 2015) no plastic bag lifestyles (Zen et al., 2013), energy savings (Zhou et al., 2015) and other spheres of consumption (Tahir and Zen, 2016). Moreover, people manage to prevent severe adverse conditions where they lack the necessary information to direct their actions (Jack and Ivanova, 2021). Household members lifestyle and behaviour like, turning off lamps, recycling cans, and going vegetarian are all effective ways to minimise carbon emissions, however, travel by air, using personal cars for moving rather using mass transit and using electricity as a heating source contribute to higher emissions (Bin and Dowlatabadi, 2005). Moreover, awareness is a necessary but not a sufficient element of social change (ERMD, 2001).

The creation of a new ' low carbon society' requires a set of guides that indicate the values and attitudes along with low carbon lifestyles. The low carbon society practices, values, attitudes, and awareness were found to effectives to control negative consequences against climate change and carbon footprint (Zen et al., 2021; Sarkar et al., 2019; Laroche et al., 2001). The low carbon society' context is an expression of ambitions to create a specific, personal, cultural and social identities that frame a society that needs to maintain certain values, attitudes, knowledge, and behaviour to sustain certain habits and social standards (Stern, 2000). In this case, the study explores what a household's carbon footprint needs, how is different insight of household awareness, level of knowledge and attitude on climate change support the low carbon practices.

Households that focus on a low carbon footprint and try to reduce climate change impacts by changing their behaviour when combined with extra incentives (e.g., due to social norms or good health). Factually, environmental awareness and behaviour change are closely linked (Zen et al., 2021; Jack and Ivanova, 2021; Poortinga et al., 2004). The majority of households in earlier studies indicated that they saved power for financial or health reasons than environmental concerns (Whitmarsh, 2009). Taking public or private transportation for reasons than environmental or climatic concerns (Poortinga et al., 2004). People continue to live sustainably because they feel obligated to do so but not based on eco-friendly concerns (Degenhardt, 2002b). Sustainable consumption is positively found to be associated with environmental attitudes, interest, efficacy, and perceived environmental effects (Levay et al., 2021; Sarker et al., 2018). Therefore, this study looked at a wide range of low-carbon attitudes and behaviours.

3. Methodology and analysis

The magnitude of Malaysian households' carbon footprints, as well as the relationship between carbon footprints and household daily activities and socioeconomic demographic variables, were statistically examined in this study. The next sections describe the detailed research method, including the study area, hypothesis development and assessment process, household carbon footprint calculation (with more details in the appendix), questionnaire and Green Attitude Index development, and analysis of household behaviours linked to concern for the environment.

3.1. Study area

This research was carried out through five local planning authorities in the 'Iskandar Malaysia' district (Fig. 1), which are overseen by the Iskandar Regional Development Authority, a federal legislative body (IRDA). Table 1A shows the socioeconomic indices of Iskandar Malaysia.

The research region is categorised into six strata: i) rural areas (Kampung Ulu Pulai), ii) non-market housing (PPRT) in Bandar Seri Alam, iii) squatters' areas in Kampung Skudai Kiri, iv) low-cost areas in Taman Pulai Perdana 2, v) medium cost urban areas in Melana Apartments, and vi) medium-high-cost areas near Taman University. Simple random sampling was used in the second stage to select one neighbourhood for each stratum. The third stage contained systematic random sampling, in which respondents were chosen randomly from the population of each selected stratum.

Thus, the survey[2] respondents were households from six separate residential areas in Iskandar Malaysia, including five urban areas and one rural area, chosen using a non-proportionate stratified sampling method (Table 1B).

There was a total of 23 questions which surveyed respondents' green attitudes at home, at work and during their shopping and recreation activities, and respondents answered questions by saying 'Never', 'Sometimes' or 'Always'. 'Never' means they do not practice a green lifestyle and 'Always' represents environmentally friendly behaviour. The list of questions related to green attitudes listed in Table 1C.

3.2. Survey data collection

The study used a stratified random sampling procedure to guarantee that the questionnaire results matched the usual criteria for discriminant validity. The survey portion of the research was carried out as a guided questionnaire. The sample size was determined using formula $S = X^2NP(1\text{-}P)/d2\ (N\text{-}1) + X^2\ NP\ (1\text{-}P)$, where S = required sample size, X^2 = value of chi-square for 1 degree of freedom at the desired confidence level, N = population size, P = population proportion (assumed to be 0.50), and d = degree of accuracy expressed as a proportion (0.05).

There were 70 sampled respondents in each group, bringing the total number of respondents to 420 (e.g., gross number), a sample which was calculated using a 95% confidence threshold and a 5% sampling error. About 100,000 households were chosen (by random clustering method) from the total population of 317,762 (e.g., from the study areas) and finally, 384 households determined to be the minimum acceptable sample size for the study outcomes to be robust. It was essential to assure the validity and reliability of the questionnaire before proceeding towards estimation. Face and construct validity (e.g., convergent and discriminant validity) techniques were used to assess the validity and reliability of the questionnaire survey data. Similarly, reliability tests were used to ensure that the constructs were random error-free and produced reliable outputs. The purpose of this step was to reduce the chances of bias and errors in the resulting estimates.

For the estimation for reliability tests, three reliability techniques were employed, i.e., average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha. The following techniques were used to ensure the validity and reliability of the data and the model. Confirmatory factor analysis (CFA) was conducted to measure convergent validity, which is commonly measured through factor loadings (>0.50) and AVE (>0.50). CFA was used to test the correlation between factors in the measurement model (<0.85). Moreover, the reliability test, which is facilitated by CFA, was used. Construct validity is also assured by careful attention to the goodness-of-fit of the model to the data employing CFA. All values surpassed our threshold values as calculated by using SPSS software.

A four-month household poll, from September to December 2017,

[2] The questionnaire was divided into three sections for this study: (i) data collection on respondents' socio-demographic information and household characteristics; (ii) measuring households' direct and indirect (secondary) carbon footprints; and (iii) carbon footprint assessment using online carbon calculation software to calculate each household's direct, secondary, and total carbon footprint.

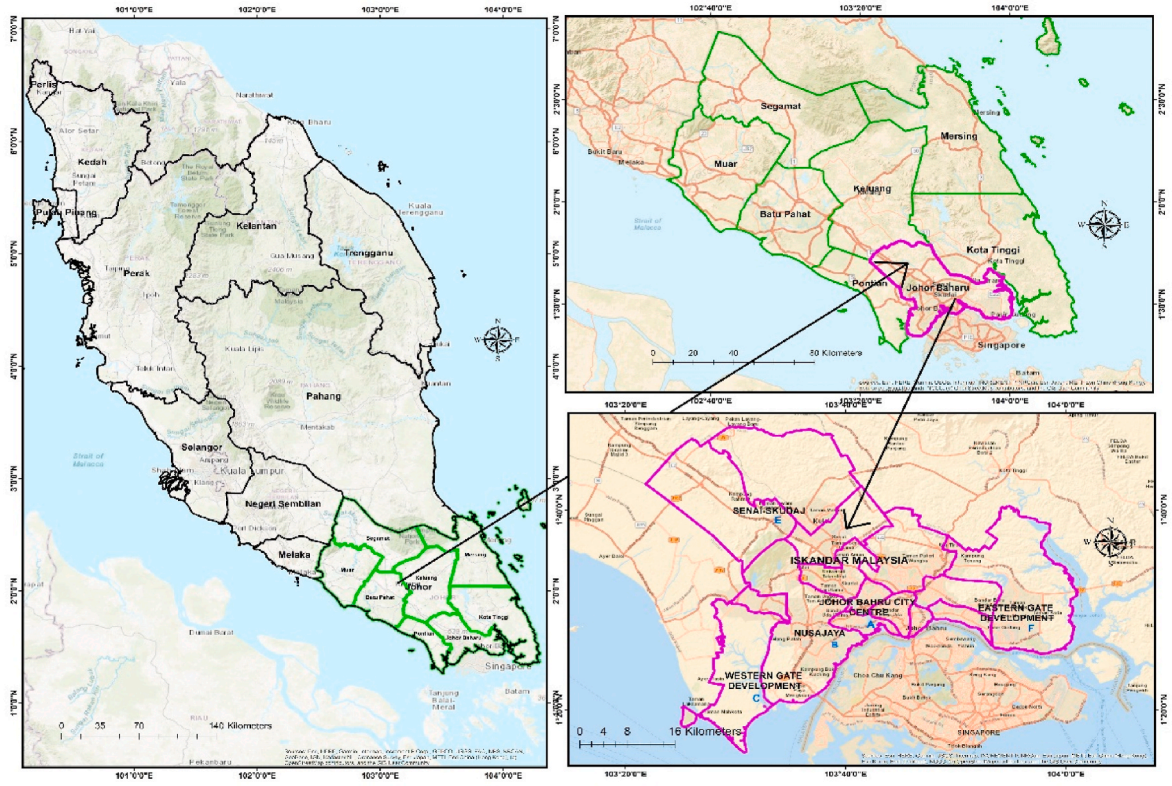

Fig. 1. Map of the study area.

Table 1A
Iskandar Malaysia's socio-economic indicators.

Indicator	2025
Population	3,005,815
No. of households	751,454
GDP (mil RM)	176,224
GDP per capita (RM/capita)	58,628
Gross output (mil RM)	474,129
Floor space for commercial (mil m^2)	19.3
Passenger transport demand (mil p-km)	8677
Freight transport demand (mil t-km)	5204

Source: IRDA (2018), US$1 = RM4.05

Table 1B
Systematic sampling in study area.

Category	GPS position (Lat, Long)	Area	Sampling segment	No. of Households	No. of Respondents
Village (rural)	1.4831495,103.5771114	Kampung Ulu Pulai	1/35 Houses	2480	70
Squatters	1.4868218,103.7116368	Kampung Skudai Kiri	1/4 Houses	323	70
Non-Market Housing	1.5148899,103.8775484	Bandar Seri Alam	1/7 Houses	476	70
Affordable Housing	1.5638594,103.6111346	Taman Pulai Perdana II	1/5 Houses	400	70
Medium Cost Housing	1.5450616,103.6282214	Melana Apartments	1/4 Houses	376	70
Medium-High-Cost Housing	1.5356146,103.6219169	Taman University and Taman MutiaraRini	1/4 Houses	325	70

included face-to-face interviews. This study's data analysis was divided into two sections. The first step was to collect data from the questionnaire survey in order to measure the carbon footprint of households. This goal was achieved using an online carbon footprint calculator[3] model. The next step was to use the SPSS (Statistical Package for the Social Sciences) programme to analyse the results.

The importance of household/individual behaviour towards the environment is a key factor to understand the consumption pattern of households, and thus affects the total carbon footprint of each household (Bin and Dowlatabadi, 2005). Households with a more sustainable or green attitude towards the environment are expected to have a smaller carbon footprint and lower contribution to global warming and carbon footprint, as measured by their behaviour. The overall result was categorised based on i) characteristics of household, ii) environmental awareness of respondents, iii) environmentally friendly lifestyle (green attitude) of respondents, iv) measurement of carbon footprint, v) comparing carbon footprint of different categories of respondents, vi) the relationship between lifestyle and socio-economic aspects of

[3] The method of analysis for (i) carbon footprint analysis, (ii) selection of carbon footprint calculator and (iii) carbon footprint calculation process is added in the appendix (as supplementary material).

Table 1C
Household low carbon practices/green household behaviour.

At home	Never	Sometimes	Always
1. Use re-chargeable battery			
2. Reuse glass bottles for other purposes			
3. Reuse plastic bags for other purposes			
4. Separate recyclable plastic/aluminium cans from other waste materials			
5. Put recyclable materials into separate plastic bags from garbage bag			
6. Bring recycled materials to recycling bins			
7. Not using food packaging from Styrofoam/ polystyrene			
8. When not in use, switch off lights			
9. When not in use, turn off fans			
10. Switch off air-conditioning system when not in use			
11. When not in use, switch off appliances completely			
12. Put appliances on standby when not in use			
At work	**Never**	**Sometimes**	**Always**
13. Practice car pooling			
14. Use public transport to work			
15. Reuse used papers/envelopes			
16. Bring my own food containers to buy food			
17. Bring my own drinking bottle			
18. Shut down or put my computer on standby when not in use			
Recreation and Shopping	**Never**	**Sometimes**	**Always**
19. Use bicycle to and from nearby houses			
20. Walk to and from nearby places			
21. Use plastic food containers provided in restaurants			
22. Refuse to use a plastic bag when purchasing small number of items			
23. Bring reusable bags to shops to avoid use of new plastic bags			

Note: (PART FOUR in the questionnaire: Household behaviour, please tick the appropriate box).

households and their carbon footprint, and vii) the effect of different variables on the carbon footprint of a household.

To explore in detail the socioeconomics determinants of household carbon footprints in Iskandar Malaysia, the hypothesis used in this study are as follow:

H0. : Green attitudes of households do not affect the total amount of carbon footprint

H1. : Green attitudes of households have a significant effect on the total amount of carbon footprint.

By using SPSS, 23 questions were converted into one compound variable to determine the green attitude index of household, which is labelled as the "green attitude index". For this purpose, the values of all 23 questions have been added together and then divided by 23 to determine the overall environmental index of each household (i.e., the minimum value for each question is 1 and the maximum value is 3). Moreover, a Pearson correlation was used to investigate the correlation among the low carbon attitudes of respondents and their total carbon footprint generated from a carbon footprint calculation (Refer to Part 1). The results were then used to identify whether there is a significant difference between the carbon footprints of green attitude respondents versus the carbon footprints of non-green attitude respondents. The strength of the association developed by Cohen et al. (2007) was adopted for use in this study. The details of the three sections are explained in detail below:

The independent variables of this research were divided into three major categories:

i The first category is socioeconomic factors, which include ethnicity, religion, household type, household size, age, education, household head's gender, household's total monthly income, and household tenure status. Some of the independent variables were categorical data and could not be used in multiple regression models; to solve this problem, dummy variables were created for categorical data like household type, religion, ethnicity, household head's gender, field of education and tenure status of households.

ii The second category, which reflects the lifestyle of households, is named the green attitude index. This part of the questionnaire includes 23 questions, which asks respondents about their green behaviours at home, at work, and during their shopping and recreation activities. Respondents answered questions by saying Never, Sometimes and Always. Never means they do not practice a low carbon/ green lifestyle at all and this non-green behaviour is consistent. By using SPSS, these 23 questions have been converted into one independent variable labelled as "Green Attitude Index". The list of 23 questions is listed in Table 1C. The equation used to convert the mean value of these 23 questions into one variable is as below:

$$\text{Green Attitude Index} = [Q1+Q2+Q3+\ldots.+Q23]/\,23\ldots\ldots\ldots\ldots \quad (1)$$

3.3. Limitation of the work

Statistics used in data analysis are limited to quantifiable characteristics of objects, and hence, rarely provide a whole solution to a problem. They provide a foundation for judgement but not the entirety of the decision. Although statistics makes extensive use of laws and equations to ensure its robustness, the conclusions obtained are usually 'supportive' rather than conclusive. As they are usually incapable of providing an absolute conclusive answer to a problem, the result must be subjected to further research with the inclusion of additional dimensions (not included in this study). Thus, the conclusions reached in this study should be used with caution for generalisations, care is needed when applying the findings.

4. Results

The socio-economic and demographic profiles of Iskandar Malaysia are as follows: people of Malaysian background made up 95.2% of all respondents, followed by Chinese (15.2%) and Indians (8.3%). 76.2% of respondents were Muslim, predominantly Malay, followed by Buddhists at 10.7%, Hindus at 6.9%, and Christians at 6.2%. Families with adult children topped the list of household types at 28.8%, followed by families with young children (25.7%) and single parents with adult children (10.5%). Other household kinds (the remaining %) were "couples without children", "single parents with young children", "Alone", and "elderly couples". In terms of household size, 23.3% of households had four individuals, followed by 19.3% and 14.5% with five and six members respectively. Male-headed households were 86.9% of the sample, while female-headed households comprised 13.1%. Educationally, 4.5% of the respondents' household heads had a secondary education, or 187 respondents. With 19.8%, "certificate/diploma" came second. Only 6% of respondents held postgraduate degrees, with 3.6% having Master's and 2.6% having PhDs. Respondents with a post-secondary education studied "engineering/technology" (13.6%), "humanities/law/management" (10.1%), "art/architecture/planning" and "pure science" (1.2%) and rest other did not disclose their education or uneducated (63%). Most responders have no post-secondary education.

The household income assessed in the survey comprised the income of the husband, wife, and all other family members (if any). A total monthly household income of RM2001-RM3000 was reported by 25.2% of respondents, followed by RM1000-RM2000 by 22.4% and RM3001-RM4000 by 16.0%. The study found that 20% of respondents earned above RM500.00 per month, but only 3% earned over RM1000.00. A single wage earner was found in 37.9% of households, followed by two

wage earners (32.4%), and roughly 20% of respondents had more than two wage workers, whereas 10% had no income earners at all and were assumed to be on welfare. In terms of home ownership, 60% of respondents owned their homes while 40% rented.

4.1. Climate change awareness

The research examined the degree to which respondents claimed to have awareness of the negative effects of climate change, finding that 83.6% of respondents' reported high awareness. Despite this self-reported high degree of awareness, only 2.6% of respondents identified (Table 2). Around 80% of respondents get their climate change information from television and radio, while 14% get it from the Internet. The remaining respondents get their information from environmental groups/NGOs (2.4%) and government activities such as green campaigns (3.3%). The findings suggest that the first step in improving educational strategy for climate change awareness in Iskandar Malaysia should be to strategize an educational awareness campaign.

Study results also demonstrated that many respondents had an awareness of the concept of carbon footprint. Around 65% of survey respondents said they were aware of their carbon footprint, while 35% said they were not, or did not know about carbon footprint. When asked to define carbon footprint, around 45% of respondents chose the correct response from four possible meanings of carbon footprint: *"The amount of carbon released in our everyday activities, such as cooking and driving"* (Table 3). Their response indicates that they acknowledge the individual role that consumption and daily activities plays in carbon emissions. Around 90% of respondents said "No" idea on their own carbon footprint assessments (e.g., respondents have no idea on how their daily activities or lifestyles affecting carbon footprint in the economy), while just 10% said "Yes" idea on their carbon footprint assessments.

The research revealed that only 13.6% of those with a high level of awareness and at least a medium level of knowledge has made some concerted efforts to reduce their carbon footprint, while an additional 8.8% have made numerous lifestyle changes to reduce their carbon footprint and are willing to do more (Table 4). 82.6% of respondents claimed to be willing to change their lifestyle to a green lifestyle in order to reduce their own carbon footprint.

4.2. Attitudes towards a low carbon lifestyle

The impact of respondents' food habits, fashion choices, and electrical and furniture use, as well as their leisure activities, packaging, and recycling attitudes, on carbon emissions were identified as part of the research (Table 5). According to survey results, almost half of households have a dietary preference for a combination of white and red meat. White meat[4] (e.g., not red) was the second most common food response for 22.9% of respondents, while 20.7% of households responded that they primarily eat fish. Just 8.3% of households declared themselves vegetarians.

Half of the respondents said they have a food choice option either organic or non-organic products, while 27.9% of households said they prefer non-organic products or would never attempt to purchase any organic goods. On the other hand, 16.2% of respondents said they only buy or grow organic goods because they prefer such food. The rest of the households were unaware of their dietary preferences regarding organic products; in other words, they had no idea if the food they were purchasing was organic or not. This category of households represents 6.2% of the total number of households surveyed in this study.

Households' lifestyles include fashion attitudes and the frequency with which household members purchase clothing. The majority of respondents have a fashion mindset, with 59.3% saying they purchase new clothes when they are needed and/or they frequently shop for the latest fashion (at least once every three months), while 12.9% of respondents said they purchase used clothing (Table 5).

Questions asked about households' attitudes toward packaging indicate that 56.7% make an effort to purchase products with little packaging, followed by 33.8% of households that only buy things that are nicely packed. These latter products tend to have a higher carbon footprint (due to the carbon emissions related to packaging materials), and the person who buys them typically has a significant secondary carbon footprint. In contrast, 9.5% of households stated they have sometimes declined to purchase a product due to its excessive packaging. The secondary carbon footprint of these respondents is assumed to be the smallest.

Respondents were asked about their expenditures on furniture, electrical appliances, and home fashion. 62.6% of respondents said they only buy what they need and use the items until they break down, while 26.4% of respondents said they buy new items and keep these for more than five years. A small percentage, 5.2% of those surveyed, said they shop often to keep up with the new technology and home fashion trends, and these individuals are thought to have a large secondary carbon footprint. 5.7% of respondents said they only buy used furniture and appliances (Table 5).

Two of the most critical aspects of a household's lifestyle are its recycling and recreational attitudes, both of which have a correlation with the amount of secondary carbon footprint produced. Around 37.1%

Table 2
Climate change definition.

Climate Change is described in a variety of ways	Change (%)
i. The weather in a particular season of the year changes	53.5
ii. Climate change in various parts of the world during the same season	25.2
iii. Changing conditions at various times of the day	18.8
iv. Over the course of decades, the weather trend has changed	2.6
Total	100

Table 3
Carbon Footprint is a term used to describe the amount of carbon emitted.

Survey: Possible Carbon Footprint Definitions	Proportion of Respondents (%)
i. The amount of CARBON released in our everyday activities, such as cooking and driving	45.7%
ii. The volume of CARBON released into the atmosphere by urban factories	30%
iii. The amount of CARBON released as a result of fertiliser and spray use, which damages the ozone layer	18.6%
iv. The average amount of carbon in the atmosphere for a certain time span	5.7%
Total	100%

Table 4
Household carbon footprint reduction to save the planet.

Self-claimed Declaration	Frequency	Response (%)
1. I'm not sure of the problems around climate change	92	21.9
2. While I am aware of climate change, I have not taken any concrete measures to reduce my carbon footprint	234	55.7
3. I've made some deliberate efforts to lower my carbon footprint.	57	13.6
4. I've made a number of lifestyle improvements to reduce my carbon footprint, and I'd like to do even more.	37	8.8
Total		100.0

[4] A combination of fish and poultry.

Table 5
The attitude of households towards a low-carbon lifestyle.

A. Attitude towards food	Frequency	Response (%)
Preference for vegetarian cuisine	35	8.3
Fish is primarily consumed as a source of nutrition	87	20.7
Preference for white meat	96	22.9
A combination of white and red meat is preferred as a meal	199	47.4
Preference for red meat	3	.7
B. Attitude towards organic products		
Preference for organic foods	68	16.2
Organic and non-organic food preferences	209	49.8
Preference for non-organic foods	117	27.9
Organic food isn't something I'm familiar with	26	6.2
C. Attitude towards fashion		
Regularly shopping for the new trends is a fashion attitude	54	12.9
When it comes to fashion, it's all about buying new clothes when they're needed	249	59.3
When it comes to fashion, people have a tendency to buy things they don't need	100	23.8
Attitude toward secondhand clothing as a fashion trend	17	4.0
D. Attitude toward packaging		
Don't buy something that has packaging around it, according to the packaging mentality	40	9.5
As far as packaging goes, I try to buy products with as little packaging as possible	238	56.7
Just buy items that are nicely packed, according to the packaging mentality	142	33.8
E. Attitudes towards furniture and electricity		
Willingness to have up-to-date innovations and home décor	22	5.2
To purchase new items but retain them for more than 5 years	111	26.4
Purchase only required equipment and use it before it breaks	263	62.6
Furniture and appliances can only be purchased secondhand	24	5.7
F. Attitude towards recycling		
Attitude that is completely recycled or composted	25	6.0
Mostly Recycled mentality	111	26.4
Attitude that has been partially recycled	156	37.1
Attitude of not recycling	128	30.5
G. Attitude towards recreation		
Only engage in zero-carbon activities, e.g., walking and cycling	132	31.4
Go to the movies, bars, and restaurants only on rare occasions	154	36.7
We also go to the movies, pubs, and restaurants	104	24.8
Participate in behaviours that produce a lot of emissions.	30	7.1

of respondents said they have a partial recycling attitude, while 30.5% of households have a non-recycling attitude. 6.0% of respondents reported that they have a fully recycled or composting mentality. Household recreational activities can also play a significant role in deciding their carbon footprint, both directly and indirectly. The results of descriptive statistics show that the majority of respondents (36.7%) rarely go to places like movies, bars, and restaurants. Simultaneously, 31.4% of respondents said they only engage in zero-carbon behaviours such as walking or cycling. 7.1% of respondents, on the other hand, enjoy carbon-intensive activities such as car or motorcycle convoys (Table 5).

4.3. Low carbon behaviour index

Research on the low carbon behavioural practices of households was comprised of a suite of 23 questions that asked about respondents' behaviours at home, at work, during recreation, and while shopping (Table 6). Using SPSS, the sum of these 23 questions was converted to one compound variable, called the "low carbon behaviour index". For this index, the values of all 23 questions were added together and then

Table 6
Low carbon practices/behaviour of households (N = 420).

A. Practices at Home	Mean	Std. Deviation
Use rechargeable battery	1.90	.831
Reusing glass bottles for other purposes	1.75	.744
Reusing plastic bags for other purposes	2.44	.707
Separating recyclable plastic/aluminium cans from other waste materials	1.96	.745
Put recyclable materials into separate plastic bags from the garbage bag	1.91	.766
Bring recycled materials to recycling bins	1.69	.750
Not using food packaging from Styrofoam/polystyrene	1.72	.699
When not in use, switch off lights	2.83	.410
When not in use, turn off fans	2.87	.347
Switch of an air-condition system when not in use	2.68	.661
Completely Switch off appliances when not in use	2.86	.372
Put appliances on standby when not in use	2.20	.793
A composite mean score	2.23	
B **Practices at Work**	Mean	Std. Deviation
Practice carpooling	1.47	.671
Use public transport to work	1.44	.639
Reusing used papers/envelopes	1.86	.714
Practice at Workplace		
Bring my own food containers to buy food	1.56	.707
Bring my own drinking bottle	2.02	.801
Shut down or put my computer to stand by when, not in use	2.03	.778
A composite mean score	**1.73**	
C **Practices During Recreation and Shopping**	Mean	Std. Deviation
Use a bicycle to and for nearby areas	1.46	.719
Walk to and for nearby places	2.04	.746
Use plastic food containers provided in restaurants	2.04	.757
Refuse to use a plastic bag when purchasing a small number of items	1.85	.620
Bring reusable bags to shop to avoid the use of plastic bags	1.78	.650
A composite mean score	1.83	
Overall Average Score/Green Behaviour Index	**1.93**	

divided by 23 to determine the average environmental index of each household (Minimum value for each question is 1 and a maximum value is 3. Higher values reflect more pro-environmental behaviours).

4.4. Multiple regression model for household carbon emissions

The study used multiple regression analysis to assess the significant factors that have the greatest impact on household carbon footprints, and to determine how much each factor influences the amount of carbon generated from household activities. The effect of each independent variable on our dependent variable, the amount of household carbon released, was determined using an online carbon footprint calculator. The calculation includes self-reported primary and secondary household carbon footprint contributions.

The statistical method used in this transformation was a stepwise approach with a collection of variables: income, residence position, green attitudes, household size, household head's level of education, tenure status, religion, age of household head, type of household, gender of household head, race, household's wage earners total income and household head's education level. The outcome was eight SPSS-suggested statistics, ranging in updated R^2 (R squared) from 0.494 to 0.601 (see Table 7). The model's lifestyle and socioeconomic factors, as well as the order in which variables are entered into the model, are reviewed in Table 7.

Model No.8 was chosen because it has an adjusted R2 value of 0.601, which means it explains about 60.1% of the total variance in the dependent variable. In regression models, this sum is considered a respectable result. The modified R^2 value is not significantly different from the R^2 value of all models. The R^2 value in our chosen model is 0.0608. We looked at the ANOVA table to see if the finding was statistically significant. According to the data in the ANOVA table, this

Table 7
A model's summary of lifestyle and socioeconomic variables.

Model	Type/Categories	Predictors (Factors)	R	R Squared	Adjusted R Squared	Std. Error of the Estimate
1.0	Income level	Monthly household income	0.70[a]	0.49	0.49	4.18
2.0	Green thinking	Owned behaviour	0.73[b]	0.53	0.53	4.05
3.0	Areas of residence	Location	0.75[c]	0.56	0.56	3.91
4.0	Household's educational standard	Ownership & education	0.76[d]	0.58	0.57	3.85
5.0	Status of tenure	Time of possession or holding of residence	0.77[e]	0.59	0.58	3.79
6.0	Age	Household head's age	0.77[f]	0.59	0.59	3.77
7.0	Family status (size)	Household size	0.78[g]	0.60	0.59	3.74
8.0	Household head's gender	Male/female	0.78[h]	0.61	0.60	3.72

[a] Predictors: (Constant), Total monthly household income.
[b] Predictors: (Constant), Total monthly household income.
[c] Predictors: (Constant), Total monthly household income, Owned Behaviour.
[d] Predictors: (Constant), Total monthly household income Owned, Behaviour, and Location.
[e] Predictors: (Constant), Total monthly household income, Behaviour, Ownership, Location, and Household Size are all factors to consider.
[f] Predictors: (Constant), Total monthly household income, Behaviour, Ownership, Place, Household Size, and Household Head's Education.
[g] Predictors: (Constant), Total monthly household income, Owned, Behaviour Household Size, Location Household Head's Education Degree, Household Head's Age.
[h] Predictors: (Constant), Total monthly household income, Owned, Behaviour Location, Household Size, Household Head's Education Level, Household Head's Age, Female.

model's outcome is statistically significant, with [Sig = 0.00, $p < 0.05$]. More information can be found in Table 8.

For each variable, the multicollinearity test, tolerance, and the Variance Inflation Factor, VIF values are determined applying the method 1–R.[2] A value of less than 0.10 suggests a high level of multiple correlations with other variables, implying multicollinearity. Table 9 shows the Tolerance VIF values for all variables in this mode. The VIF for checking multicollinearities for all independent variables has a value less than 10, indicating that the multicollinearity assumption has not been violated and that there is no multicollinearity among the predictor variables.

Table 9 reveals that 5 of the 13 variables that registered were omitted because they did not contribute significantly to the model. Religion, ethnicity, household type, household head's field of education, and the wage earners' number in a household are among the 5 variables omitted. Eight (8) independent variables, on the other hand, play a significant role in predicting household carbon footprint remained in the model. These include household income, green attitude, residence area, household carbon footprint, tenure status of the household, household head's education level, household size, age of household head, and gender of household head are the eight variables.

The Beta value was used to see which of the model's independent variables contributed the most to the dependent variable's estimation. The findings indicate that among all variables, "Household Income" has the greatest impact on calculating a household's carbon footprint (=0.476, $p < 0.05$). The findings were duly indicated by green attitude ($\beta = -0.196$, $p < 0.05$) and area of residence ($\beta = 0.157$, $p < 0.05$). The educational level of the household head is another significant indicator of a household's carbon footprint ($\beta = 0.131$, $p < 0.05$), as are the tenure status of the household ($\beta = 0.130$, $p < 0.05$), household head's age ($\beta = 0.112$, $p < 0.05$), household's size ($\beta = 0.101$, $p < 0.05$) and household head's sex ($\beta = -0.077$, $p < 0.05$). A standard likelihood plot of regression is shown in Fig. 3. For example, for 1 standard deviation increase in income, the model predicts a carbon footprint increase of 0.472 standard deviations, while for 1 standard deviation increase in green attitude, the carbon footprint decreases by 0.192 standard deviation. Fig. 2 indicates that the data are normally distributed. Based on the results of multiple regression, the equation for the model of this research is presented as below:

$$Y = 7.73 + 1.11\,X_1 - 4.18\,X_2 + 0.52\,X_3 + 1.58\,X_4 + 0.61\,X_5 + 0.30\,X_6 + 0.04\,X_7 - 1.61\,X_8 - 1.02\,X_9 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

Y Household's carbon footprint
X1 Total household monthly income (in Malaysian Ringgit)
X2 Green attitude Index
X3 Residence location and housing type (residential area)
X4 Tenure status of household (house ownership: owner or tenant)
X5 Household head's education (years of education)
X6 Family size (number of people in the household)
X7 Head of household's age
X8 Sex of the household head (female or male)
X9 Type of household (composition of household members)

Table 8
Regression model test outcomes by ANOVA.

Sum of Squares	df
8817.023	8
5674.378	411
14491.401	419

h. Predictors: (Constant), Total monthly household income, Owned, Behaviour Location, Household Size, Household Head's Education Level, Household Head's Age, Female
i. Dependent Variable: Total CF

4.5. Household carbon footprint: socio-economic determinants: significant variables

A summary of the result of the household's socio-economic predictors and carbon footprint is presented in Table 10. The most significant indicator of carbon footprint is income ($\beta = 0.476$, $p < 0.05$) showing that for any increase in a household's income there is a significant risk that the carbon footprint of that particular household would increase. Consumers with more money have the ability to purchase more appliances and amenities for their houses, as well as more personal vehicles for family members. The result is commonly found in similar research carried out in other countries such as China, India and UK (Grunewald et al., 2012; Liu et al., 2013; Minx et al., 2009).

The second significant predictor of carbon footprint is a household's green attitude ($\beta = -0.196$, $p < 0.05$), however, the correlation is in a negative direction, meaning that any strengthening of one's or a family's green attitudes will likely result in a smaller carbon footprint. Low-carbon living refers to a society's low-carbon mindset/attitudes and associated behaviours.

The third predictor is the residential area where the household is situated in the metropolitan area; Bandar Seri Alam, Kampung Skudai Kiri, Taman Pulai Perdana-2 and Taman University make larger carbon footprint contributions than households in the rural area of Kampung

Table 9
Values of the lifestyle model's coefficients.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
(Constant)	7.22	1.81		4.00	.000					
Total monthly household income	1.12	0.10	0.48	11.10	.000	0.70	0.48	.34	0.52	1.93
Environmental Consciousness	−4.25	0.69	−0.19	−6.18	.000	−0.29	−0.29	.19	0.95	1.05
Status of Tenure	1.55	0.41	0.13	3.75	.000	0.32	0.18	.12	0.79	1.27
Areas of Residence	0.54	0.13	0.16	4.26	.000	0.48	0.21	.13	0.71	1.42
Size of the Family	0.29	0.09	0.10	2.96	.003	0.16	0.14	.09	0.84	1.22
Level of education	0.61	0.19	0.13	3.14	.002	0.46	0.15	.09	0.55	1.84
Household Head's Age	0.06	0.02	0.11	3.07	.002	0.10	0.15	.09	0.71	1.41
Household Head's Gender	−1.34	0.55	−0.08	−2.44	.015	−0.15	−0.12	-.08	0.95	1.05

a. Dependent Variable: Total CF.

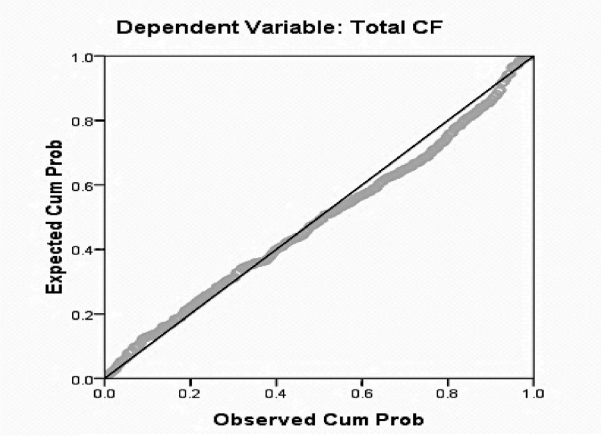

Fig. 2. Regression model normal probability plot.

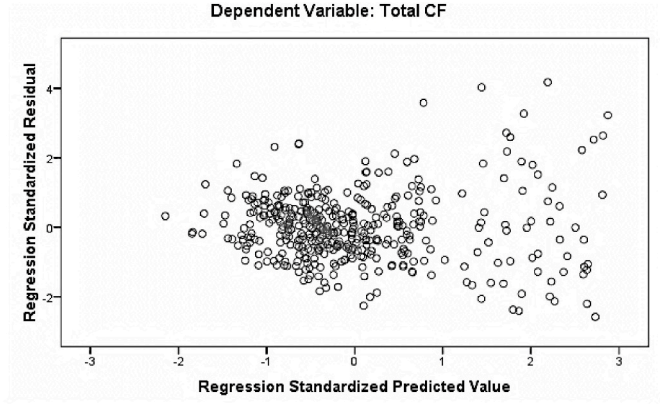

Fig. 3. Scatterplot of residuals.

Ulu Pulai ($\beta = 0.157$, $p < 0.05$). In comparison to the gap between the residential area and the nearby business district, the household in the urban area consists of a mix of single and double-story residential buildings which requires high carbon emitting transportations.

Examining the relationship between education level and carbon footprint, this fourth predictor showed two distinct trends (Table 10). Heads of households who do not have higher education demonstrate higher level of carbon footprints. Households with a head who has a university education, demonstrate lower carbon footprints, and these footprints decrease as the level of education increases ($\beta = 0.131$, $p < 0.05$). To put it another way, individuals who have more education tend to have a smaller carbon footprint than people who don't have as much education, likely as a result of increased environmental consciousness and sensitivity to the impacts of climate change and global warming. Thus, one of the variables that appears to reduce carbon footprints is higher education attainment.

Table 10
Household carbon footprint predictors.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Rank	Predictor	B	Std. Error	Beta		
1	Level of income	1.12	0.10	0.48	11.10	0.000
2	Green thinking	−4.25	0.69	−0.19	−6.18	0.000
3	Areas of residence	0.54	0.13	0.16	4.26	0.000
4	Household head's educational standard	0.62	0.19	0.13	3.14	0.002
5	Status of tenure	1.55	0.42	0.13	3.75	0.000
6	Age	0.06	0.02	0.11	3.07	0.002
7	Size of the family	0.29	0.09	0.101	2.96	0.003
8	Household head's gender	−1.34	0.56	−0.08	−2.44	0.015

Home ownership or tenure status is the fourth important predictor of the amount carbon footprint of household ($\beta = 0.133$, $p < 0.05$) (Table 10). The mean carbon footprint of households who own their home and those who rent a home differs in a manner which is statistically significant, with homeowners having a significantly higher carbon footprint than those who rent.

Several additional factors play a role in a household's carbon footprint. The results of the regression model show that in Iskandar Malaysian households, the age of the household head is a significant indicator of total carbon footprint ($\beta = 0.095$, $p < 0.05$). The number of household members, or the size of the household, is an important measure of the overall amount of carbon footprint ($\beta = 0.106$, $p < 0.05$), with an increased size of the household members resulting in a rise in the total amount of carbon footprint. Gender of the household head is also an important indicator in predicting the total carbon footprint of a household in Iskandar Malaysia. There is a statistically significant difference ($\beta = -0.077$, $p < 0.05$), in carbon footprint between households with female householders and those with male householders. Female-headed households consume less and, as a result, produce fewer carbon emissions than male-headed households. The household head's gender is thus a significant predictor of a household's overall carbon footprint.

Another variable that was expected to be a significant measure of carbon footprint is the type of household or the combination of households. The research revealed that the mean carbon footprint values of different household combinations varied in a statistically significant

manner. Families with mature/adult children had the highest carbon footprint, while aged couples had the lowest. Although there is a small connection between the number of wage earners in a household and the overall household carbon footprint, it is insufficient to justify the use of a regression model. In Iskandar Malaysia, regardless of how many people contributed to the total household income, the total household income is more important to the carbon footprint than is the number contributing to income.

5. The study's discussion and implications

The research investigated the issues and consumption patterns with associated variables such as climate change understanding, attitudes, and knowledge, to better comprehend the complicated linkages between socioeconomic variables and carbon emissions at household level from their spending and lifestyle patterns. The research finds that 83.6% understanding of climate change and 2.6% value on the right concept of climate change, which is similar to early surveys on climate change public opinion, which described as loose information (Abuelgasim and Daiban, 2017). Specific understanding on the subject of climate change has significant relations with an individual's level of awareness, attitude and behaviour (Lorenzoni et al., 2007). In terms of climate change, significant decreases in carbon emissions are related to changes in levels of consumption and economic activities. Scientists have discovered a link between carbon emissions, economic activities, consumption and global warming. Climate models and historical data combined to indicate a simple linear link between total cumulative emissions and global climate change (IPCC et al., 2014). Developed countries depend on viable mitigation of climate change solutions (Ali et al., 2018; Druckman and Jackson, 2009, 2010), which focuses on overall consumption as the source of today's environmental crisis, and the fact that more affluence and associated overconsumption may not be sufficient to mitigate the current environmental crisis (Jackson, 2011). In response towards that, there is a movement to counteract overconsumption by promoting a simple lifestyle (Ballantine and Creery, 2010) or minimizing consumption (Hamilton, 2010). A decline in the number of consumption of goods, services and products indicates change in consumption behaviours, such as avoiding purchasing recent product with high carbon emission and/or purchasing secondhand items, for example, buying fewer clothes or reducing living space, recycle or upcycle product and recreation towards zero carbon activities e.g., walk and cycle.

The study like others in various countries, shows that income is the strongest determinant for household carbon emissions, and is needed in order to accurately calculate the carbon footprint of a household. Green attitudes, household location (i.e., residential area), housing type, status of tenure of the household, education level of the household head, size of household, and household head's age are the additional socio-economic determinants that contribute in a positive direction to the household's carbon footprint. Only one factor, the gender of household head, has variable contribution, meaning that households that are female-headed tend to practice lower carbon lifestyles than male-headed households. However, the research has demonstrated that in Iskandar Malaysia, rural and urban lifestyles are broadly similar in terms of the characteristics that matter most to carbon footprints (e.g., electrical appliance use, lifestyles, and car use). Different scenarios have been captured in other settings where there is a greater disparity between rural and urban development. In China for example, there are greater differences between the home electrical and heating devices found in urban households as compared to rural households: according to the State Statistical Bureau 2008, the number of electrical applications, especially air conditioners, used in urban households increased three times that of rural households, and 5.5 times for computers use (Feng et al., 2011).

This study indicates that numerous socio-economic determinants can affect household carbon footprints either positively or negatively. However, more detailed studies that include other lifestyle characteristics are needed in order to get more accurate information on consumer behaviours and carbon footprints, or what marketing practitioners refer to as a 'geodemographic approach' of "analysis of people by where they live" (Harris et al., 2007). Only a few studies exist that have begun to look at the connection between carbon footprints and lifestyle analysis via geodemographic data (Duchin, 1998; Duchin and Hubacek, 2003; Druckman and Jackson, 2009; Minx et al., 2009). Information such as the type of public transportation used, both private or public, commuting requirements, the distance to stores, and the condition and the age of the housing stock are all required. The concept behind geodemographics is that people and places are inextricably linked. The knowledge of people's whereabouts reveals details about them, which in turn affects carbon footprints. People who lead similar lives are said to congregate in specific locations (Schelling, 1969; Harris et al., 2007; Pancs and Vriend, 2007; Vickers and Rees, 2007). "Villages of wealthy commuters", "affluent urban workers, big flats" or "single elderly people, high-rise flats" are examples of geodemographic lifestyle categories which likely have similar carbon emissions (Boardman, 2007). This classification gives a more meaningful result in the context of urban-rural preparation for low carbon development in the near future.

One criticism of input-output based lifestyle studies is the typically descriptive nature of the analysis of results. Several experiments have been conducted in order to estimate the amount of emissions associated with various consumption habits based on socioeconomic variables such as schooling, income, or gender to recognize the connection between lifestyles and emissions (Salo et al., 2021; Kees Vringer and Blok, 2000; Weber and Perrels, 2000; Ferrer-i-Carbonell and Van Den Bergh, 2004; Lenzen et al., 2006; Weber and Matthews, 2008; Hertwich and Peters, 2009). No study in Malaysia has yet recognized the role of lifestyles in clarifying emissions and taken them into account in empirical studies as emissions determinants. The model of important lifestyle and socio-economic build in this study reveal factors that have an effect on carbon footprint. The findings indicate that household income ($\beta = 0.476$, $p < 0.05$), green attitude ($\beta = -0.196$, $p < 0.05$), residential area ($\beta = 0.157$, $p < 0.05$), education level ($\beta = 0.131$, $p < 0.05$), tenancy standing of household ($\beta = 0.130$, $p < 0.05$), household head's age ($\beta = 0.112$, $p < 0.05$), size of household ($\beta = 0.101$, $p < 0.05$) and household head's gender ($\beta = -0.077$, $p < 0.05$) are all affecting a household's carbon footprint to some extent. Following the outcomes, we have recommended that improvements to environmental awareness, and improvement in infrastructure and green technologies, are critical if local authorities are to make progress towards a low carbon Iskandar Malaysia.

The research findings revealed that income was the most important factor increasing carbon emissions when calculating a household's carbon footprint (see Lévay et al., 2021; Christis et al., 2019). As a result, policy implications may need to include some corresponding suggestions on higher-income households. People's lifestyles, particularly in cities, have evolved over time and are currently heavily reliant on electric household facilities, businesses, and portable appliances, so there needs to be innovation in renewable technologies that consume less energy and release less carbon. If this ambition is to be accomplished, local manufacturers must be encouraged to develop more green household appliances. Local governments should also employ eco-labelling to impose control over trading enterprises in order to ensure that they import energy-efficient products when it comes to imported equipment. This will go a long way toward reducing urban residential energy consumption, which is the second-largest source of carbon emissions in Iskandar Malaysia.

According to study outcomes, "for higher-income individuals, the determinant of carbon emission to the carbon footprint is a function of preference," while "for lower-income individuals, the determinant of carbon emission to the carbon footprint is a function of constraints." Higher-income households frequently use more energy, while low-income households emit a significant amount of carbon since they do not have the choice to switch to sustainable low energy-based alternative appliances. However, we do not believe that individual preferences

and initiatives will be enough to fix this problem. Decarbonizing electrical systems, using energy-efficient equipment, and developing renewable energy sources that consume less energy and emit less carbon are some feasible solutions in future, though, policymakers should impose a specific strategy based on national low carbon economic plans. Improving infrastructure and services, as well as promoting green technologies, are two more options for Iskandar Malaysia to attain a low-carbon society. In this instance, large-scale structural transitions of energy infrastructure are required, as high-income households necessitate structural changes to our energy system.

Despite this study's limitations, we contend that the findings of this study are useful for policy development in Malaysia and other countries with similar economic environments. Noting that this study only looked at carbon dioxide emissions (e.g., kg CO2) and household's carbon footprint, more research is needed to gain a better understanding of other carbon-related emissions, such as the primary sources of greenhouse gases or GHG emissions (kg CO2-eq), greenhouse gases of special concern (e.g., methane), and specific climate change's effects on specific behaviours.

6. Conclusion

The study investigated lifestyle and socioeconomic factors that had a substantial impact on Iskandar Malaysia's carbon footprint and emissions. It also showed which socioeconomic indicators were more predictive of a household's carbon footprint and which were less predictive. According to this study, income, green behaviour, residential zone, tenure status, degree of education, the age of the household head, the size of the household, and the gender of the household head are the most relevant criteria for determining a home's carbon footprint. In Iskandar Malaysia, a variety of statistical approaches were employed to determine the impact of household lifestyle and socioeconomic factors on carbon footprint. Only 2.6% of Iskandar Malaysians comprehend climate change, despite the fact that over 80% say they do. They have a different perspective on climate change in its current state. There is a need for increased campaigning for low-carbon household lifestyles and consumption to combat climate change. Environmental campaigns in government offices, colleges, schools, and universities can be pivotal to increase society environmental awareness through a number of activities ranging from television shows to the internet. Another strategy to increase societal awareness of environmental issues is to fund environmental non-governmental organizations (NGOs). Over 82% of respondents agree to alter their lifestyle in order to reduce carbon emissions, which is a favorable reaction. This demonstrates an ability to adjust to the evolving environment. Malaysia is a good place to do more detailed and comprehensive research. Future research should focus on reducing the impact of lifestyle and socioeconomic factors on carbon emissions in the country. In terms of energy consumption, it will be good to look into the different ways that people use energy in their houses. To learn more about low carbon scenario planning and preparedness, the geo-demographic segmentation used in this study could be useful in the future. Ethnic group or job status could also be probed as potentially important sociodemographic factors linked to carbon footprints. It would be good to repeat this study on an individual level instead of a household level and compare the results. This way, we can see how each person's consumption of household goods and perceptions on climate change changes over time.

CRediT authorship contribution statement

Irina Safitri Zen: Conceptualization, Methodology, Writing – original draft. **M. Salim Uddin:** Methodology, Introduction, discussion and revised MS preparation. **Abul Quasem Al-Amin:** Methodology, Research method, discussion, policy implication and conclusion. **Mohammad Rafee Bin Majid:** Methodology, and revised MS preparation. **Abdulaziz I. Almulhim:** Writing – review & editing, Visualization, Investigation. **Brent Doberstein:** Writing – review & editing, Visualization, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The first author thanks Universiti Teknologi Malaysia (UTM) and Ministry of Education of Malaysia for the partial financial support provided by Research University Grant, Tier 1 (Project Code: 18H14). The second author is indebted to the Social Sciences and Humanities Research Council (SSHRC) of Canada for a Post-Doctoral Fellowship (# 756-2019-02920).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2022.131256.

References

Abdullah Chik, N., Rahim, K., Radam, A., Shamsudin, M.N., 2013. Impact of Malaysian industrial energy use on carbon dioxide emissions. Pertanika J. Soc. Sci. Humanit. 21, 13–28.

Abuelgasim, A., Daiban, S., 2017. Levels of climate change awareness in the United Arab Emirates. Horizons Humanit. Soc. Sci. 2 (2), 42–53.

Alfredsson, E., 2002. Green Consumption Energy Use and Carbon Dioxide Emission. Umeå University, Faculty of Social Sciences.

Ali, G., Anbren, S., Bashir, M.K., 2018. Climate mitigation, low-carbon society, and dynamism of educational institutes in a low-income country. Environ. Sci. Pollut. Res. 25, 3775–3784. https://doi.org/10.1007/s11356-017-0607-9.

Alicia, B., Prado, A., Samaniego, J., Perez, R., 2012. Sustainable Development 20 Years on from the Earth Summit: Progress, Gaps and Strategic Guidelines for Latin America and the Caribbean. United Nations.

Baiocchi, G., Minx, J.C., Hubacek, K., 2010. The Impact of Social Factors and Consumer Behavior on CO2 Emissions in the UK: A Panel Regression Based on Input-Output and Geo-Demographic Consumer Segmentation Data.

Ballantine, P.W., Creery, S., 2010. The consumption and disposition behaviour of voluntary simplifiers. J. Consum. Behav. An Int. Res. Rev. 9 (1), 45–56.

Baltruszewicz, M., Steinberger, J.K., Ivanova, D., Brand-Correa, L.I., Paavola, J., Owen, A., 2021. Household final energy footprints in Nepal, Vietnam and Zambia: composition, inequality and links to well-being. Environ. Res. Lett. 16, 025011 https://doi.org/10.1088/1748-9326/abd588.

Begum, R.A., Sohag, K., Abdullah, S.M.S., Jaafar, M., 2015. CO2 emissions, energy consumption, economic and population growth in Malaysia. Renew. Sustain. Energy Rev. 41, 594–601.

Bin, S., Dowlatabadi, H., 2005. Consumer lifestyle approach to US energy use and the related carbon emissions. Energy Pol. 33 (2), 197–208.

Boardman, B., 2007. Examining the carbon agenda via the 40% House scenario. Build. Res. Inf. 35, 363–378.

Büchs, M., Schnepf, S.V., 2013. Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. ecolgical Econ 90, 114–123.

Christis, M., Breemersch, K., Vercalsteren, A., Dils, E., 2019. A detailed household carbon footprint analysis using expenditure accounts – case of Flanders (Belgium). J. Clean. Prod. 228, 1167–1175. https://doi.org/10.1016/j.jclepro.2019.04.160.

Cohen, L., Manion, L., Morrison, Keith, 2007. Research Methods in Education, sixth ed. Routledge Falmer, New York.

DEFRA, 2008. A Framework for Proenvironmental Behaviours. London.

Degenhardt, L., 2002a. Why do people act in sustainable ways? Results of an empirical survey of lifestyle pioneers. Psychol. Sustain. Dev. 123–147.

Degenhardt, L., 2002b. Why do people act in sustainable ways? Results of an empirical survey of lifestyle pioneers. Psychol. Sustain. Dev. 123–147.

Druckman, A., Jackson, T., 2010. The bare necessities: how much household carbon do we really need? Ecol. Econ. 69 (9), 1794–1804.

Druckman, A., Jackson, T., 2009. The carbon footprint of UK households 1990–2004: a socio-economically disaggregated, quasi-multi-regional input–output model. Ecol. Econ. 68 (7), 2066–2077.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K.R., Ceron, J.P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V.R., Sauerborn, R., 2019. It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. Energy Res. Social Sci. 52, 144–158. https://doi.org/10.1016/j.erss.2019.02.001.

Duchin, F., 1998. Structural Economics: Measuring Change in Technology, Lifestyles, and the Environment. Island Press.
Duchin, F., Hubacek, K., 2003. Linking social expenditures to household lifestyles. Futures 35 (1), 61–74.
ERMD, 2001. No Title.
Farabi, A., Abdullah, A., Setianto, R.H., 2019. Energy consumption, carbon emissions and economic growth in Indonesia and Malaysia. Int. J. Energy Econ. Pol. 9 (3), 338–345.
Feng, Z.H., Zou, L.L., Wei, Y.M., 2011. The impact of household consumption on energy use and CO 2 emissions in China. Energy 36 (1), 656–670.
Ferrer-i-Carbonell, A., Van Den Bergh, J.C., 2004. A micro-econometric analysis of determinants of unsustainable consumption in The Netherlands. Environ. Resour. Econ. 27 (4), 367–389.
Grunewald, N., Harteisen, M., Lay, J., Minx, J., Renner, S., 2012. The carbon footprint of Indian households. In: General Conference of the International Association for Research in Income and Wealth. Boston.
Hamilton, C., 2010. Consumerism, self-creation and prospects for a new ecological consciousness. J. Clean. Prod. 18 (6), 571–575.
Haron, S.A., Paim, L., Yahaya, N., 2005. Towards sustainable consumption: an examination of environmental knowledge among Malaysians. Int. J. Consum. Stud. 29 (5), 426–436.
Harris, R., Johnston, R., Burgess, S., 2007. Neighborhoods, ethnicity and school choice: developing a statistical framework for geodemographic analysis. Popul. Res. Pol. Rev. 26 (5–6), 553–579.
Heinonen, J., Junnila, S., 2011. A Carbon Consumption Comparison of Rural and Urban Lifestyles 1234–1249. https://doi.org/10.3390/su3081234.
Hertwich, E.G., Peters, G.P., 2009. Carbon footprint of nations: a global, trade-linked analysis. Environ. Sci. Technol. 43 (16), 6414–6420.
Household Expenditure Survey, 2005. Household Expenditure Survey, DOS. Kuala Lumpur, Malaysia.
IPCC, 2014. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T., Minx, J.C. (Eds.), 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 University Press, Cambridge, United Kingdom and New York, NY, USA.
IRDA, 2018. Demographic Information. Iskandar Regional Development Authority, Malaysia.
Ivanova, D., Vita, G., Steen-Olsen, K., Stadler, K., Melo, P.C., Wood, R., Hertwich, E.G., 2017. Mapping the carbon footprint of EU regions. Environ. Res. Lett. 12, 054013.
Jack, T., Ivanova, D., 2021. Small is beautiful? Stories of carbon footprints, socio-demographic trends and small households in Denmark. Energy Res. Social Sci. 78, 102130. https://doi.org/10.1016/j.erss.2021.102130.
Jackson, A.L., 2011. Renewable energy vs. biodiversity: policy conflicts and the future of nature conservation. Global Environ. Change 21 (4), 1195–1208.
Laroche, M., Bergeron, J., Barbaro-Forleo, G., 2001. Targeting consumers who are willing to pay more for environmentally friendly products. J. Consum. Market. 18 (6), 503–520.
Lee, J., Taherzadeh, O., Kanemoto, K., 2021. The scale and drivers of carbon footprints in households, cities and regions across India. Global Environ. Change 66, 102205. https://doi.org/10.1016/j.gloenvcha.2020.102205.
Lenzen, Manfred, 1998. Primary energy and greenhouse gases embodied in Australian final consumption: an input–output analysis. Energy Pol. 26, 495–506. https://doi.org/10.1016/S0301-4215(98)00012-3.
Lenzen, M., Wier, M., Cohen, C., Hayami, H., Pachauri, S., Schaeffer, R., 2006. A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan. Energy 31 (2–3), 181–207.
Lévay, P.Z., Vanhille, J., Goedemé, T., Verbist, G., 2021. The association between the carbon footprint and the socio-economic characteristics of Belgian households. Ecol. Econ. 186 https://doi.org/10.1016/j.ecolecon.2021.107065.
Liu, Y., Zhang, M., Liu, R., 2020. The impact of income inequality on carbon emissions in China: a household-level analysis. Sustainability 12, 2715. https://doi.org/10.3390/su12072715.
Liu, W., Spaargaren, G., Heerink, N., Mol, A.P., Wang, C., 2013. Energy consumption practices of rural households in north China: basic characteristics and potential for low carbon development. Energy Pol. 55, 128–138.
Lorenzoni, I., Nicholson-Cole, S., Whitmarsh, L., 2007. Barriers perceived to engaging with climate change among the UK public and their policy implications. Global Environ. Change 17 (3–4), 445–459.
Malaysia National Climate Change Policy, 2010.
Minx, J.C., et al., 2009. Input–output analysis and carbon footprinting: an overview of applications. Econ. Syst. Res. 21 (3), 187–216.
Moser, S., Kleinhückelkotten, S., 2018. Good intents, but low impacts: diverging importance of motivational and socioeconomic determinants explaining pro-environmental behavior, energy use, and carbon footprint. Environ. Behav. 50, 626–656. https://doi.org/10.1177/0013916517710685.
Nor, N.H.M., Selamat, S.N., Abd Rashid, M.H., Ahmad, M.F., Jamian, S., Kiong, S.C., et al., 2016, June. Carbon sequestration and carbon capture and storage (CCS) in Southeast Asia. J. Phys. Conf. 725 (No. 1), 012010). IOP Publishing.
Ottelin, J., Heinonen, J., Nassen, J., Junnila, S., 2019. Household carbon footprint patterns by the degree of urbanisation in Europe. Environ. Res. Lett. 14, 114016.
Pachauri, R.K., Mayer, l, 2015. Climate Change 2014; Synthesis Report. Intergovernmental Panel on Climate Change, Geneva, Switzerland.
Pancs, R., Vriend, N.J., 2007. Schelling's spatial proximity model of segregation revisited. J. Publ. Econ. 91 (1–2), 1–24.
Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J. van der, Hanson, C.E. (Eds.), 2007. n Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
Poortinga, W., Steg, L., Vlek, C., 2004. Values, environmental concern, and environmental behavior: a study into household energy use. Environ. Behav. 36 (1), 70–93.
Ritchie, R., Roser, M., 2020. CO_2 and greenhouse gas emissions. Published online at OurWorldInData.org. Retrieved from. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions. (Accessed 25 March 2021).
Safaai, M., Sharliza, Nor, Zainon, Z., Hashim, H., Ujang, Z., Talib, J., 2011. Projection of CO 2 emissions in Malaysia. Environ. Prog. Sustain. Energy 30 (4), 658–665. https://doi.org/10.1002/ep.10512.
Saidur, R., Masjuki, H., Jamaluddin, M., Ahmed, S., 2007. Energy and associated greenhouse gas emissions from household appliances in Malaysia. Energy Pol. 35 (3), 1648–1657.
Salo, M., Savolainen, H., Karhinen, S., Nissinen, A., 2021. Drivers of household consumption expenditure and carbon footprints in Finland. J. Clean. Prod. 289, 125607. https://doi.org/10.1016/j.jclepro.2020.125607.
Sarkar, M.S.K., Al-Amin, A.Q., Filho, W.L., 2019. Revisiting the social cost of carbon after INDC implementation in Malaysia: 2050. Environ. Sci. Pollut. Res. 26, 6000–6013. https://doi.org/10.1007/s11356-018-3947-1.
Sarker, M.N.I., Hossin, M.A., Hua, Y.X., Anusara, J., Warunyu, S., Chanthamith, B., et al., 2018. Low carbon city development in China in the context of new type of urbanization. Low Carbon Econ 9 (1), 45–61.
Schelling, T.C., 1969. Models of segregation. Am. Econ. Rev. 59 (2), 488–493.
Serino, M.N., Klasen, S., 2015. Estimation and determinants of the Philippines' household carbon footprint. Develop. Econ. 53 (1), 44–62.
Sköld, B., Baltruszewicz, M., Aall, C., Andersson, C., Herrmann, A., Amelung, D., Barbier, C., Nilsson, M., Bruyère, S., Sauerborn, R., 2018. Household preferences to reduce their greenhouse gas footprint: a comparative study from four European cities. Sustain 10. https://doi.org/10.3390/su10114044.
Spaargaren, G., Oosterveer, P., 2010. Citizen-consumers as agents of change in globalizing modernity: the case of sustainable consumption. Sustainability 2 (7), 1887–1908.
Stern, P.C., 2000. New environmental theories: toward a coherent theory of environmentally significant behavior. J. Soc. Issues 56 (3), 407–424.
Tahir, N., Zen, I.S., 2016. Consumer perception on knowledge, attitude and behaviour towards climate change : case study of Melaka. Proceeding Int. Conf. Soc. Econ. Dev. Universiti Malaysia Terengganu. November 3rd – 4t.
Thøgersen, J., 2005. How may consumer policy empower consumers for sustainable lifestyles? J. Consum. Pol. 28, 143–177. https://doi.org/10.1007/s10603-005-2982-8.
Tian, X., Chang, M., Lin, C., Tanikawa, H., 2014. China's carbon footprint: a regional perspective on the effect of transitions in consumption and production patterns. Appl. Energy 123, 19–28.
Tukker, A., Jansen, B., 2006. Environmental impacts of products: a detailed review of studies. J. Ind. Ecol. 10 (3), 159–182.
UNFCCC, 2015. Paris Agreement. United Nations.URL: https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
United Nation General Assembly, 1992. Agenda 21.
Vickers, D., Rees, P., 2007. Creating the UK National Statistics 2001 output area classification. J. R. Stat. Soc. Ser. A (Statistics Soc. 170 (2), 379–403.
Vringer, K., Blok, K., 2000. Long-term trends in direct and indirect household energy intensities: a factor in dematerialisation? Energy Pol. 28 (10), 713–727.
Wang, Y., Zhao, H., Li, L., Liu, Z., Liang, S., 2013. Carbon dioxide emission drivers for a typical metropolis using input-output structural decomposition analysis. Energy Pol. 58, 312–318. https://doi.org/10.1016/j.enpol.2013.03.022.
Weber, Christoph, Perrels, A., 2000. Modelling lifestyle effects on energy demand and related emissions. Energy Pol. 28, 549–566. https://doi.org/10.1016/S0301-4215(00)00040-9.
Weber, C., Perrels, A., 2000. Modelling lifestyle effects on energy demand and related emissions. Energy Pol. 28 (8), 549–566.
Weber, C.L., Matthews, H.S., 2008. Quantifying the global and distributional aspects of American household carbon footprint. Ecol. Econ. 66 (2–3), 379–391.
Whitmarsh, L., 2009. Behavioural responses to climate change: asymmetry of intentions and impacts. J. Environ. Psychol. 29 (1), 13–23.
Wiedenhofer, D., Guan, D., Liu, Z., Meng, J., Zhang, N., Wei, Y.M., 2017. Unequal household carbon footprints in China. Nat. Clim. Change 7, 75–80. https://doi.org/10.1038/nclimate3165.
Zen, I.S., Abul Quasem, A.A., Mohammad, Z.F., Ahmad, M.H., Syed Ariffin, S.A.I., Fizri, F.F.A., 2016. Mainstreaming climate adaptation and mitigation policy in Malaysia: case study of Melaka city. In: Proc. 2016 Int. Symp. Sustain. Dev. Manag. (ISSDM 2016) – UTM IBS. Universiti Teknol. Malaysia, Malaysia. Oct. 8-9.
Zen, I.S., Ahamad, R., Omar, W., 2013. No plastic bag campaign day in Malaysia and the policy implication. Environ. Dev. Sustain. 15 (5), 1259–1269.
Zen, I.S., Noor, Z.Z., Yusuf, R.O., 2014. The profiles of household solid waste recyclers and non-recyclers in Kuala Lumpur, Malaysia. Habitat Int 42, 83–89.
Zen, I.S., Siwar, C., 2015. An analysis of household acceptance of curbside recycling scheme in Kuala Lumpur, Malaysia. Habitat Int 47, 248–255.
Zen, I.S., Al-Amin, A.Q., Doberstein, B., 2019. Mainstreaming climate adaptation and mitigation policy: towards multi-level climate governance in Melaka, Malaysia. Urban Clim 30, 100501.

Zen, I.S., Al-Amin, A.Q., Alam, M.M., Doberstein, B., 2021. Magnitudes of households' carbon footprint in Iskandar Malaysia: policy implications for sustainable development. J. Clean. Prod. 315, 128042.

Zhang, J., Yu, B., Cai, J., Wei, Y.M., 2017. Impacts of household income change on CO2 emissions: an empirical analysis of China. J. Clean. Prod. 157, 190–200. https://doi.org/10.1016/j.jclepro.2017.04.126.

Zhou, Z.J., Liu, X.W., Zhao, B., Chen, Z.G., Shao, H.Z., Wang, L.L., Xu, M.H., Zhou, Z.J., Liu, X.W., Zhao, B., Chen, Z.G., Shao, H.Z., Wang, L.L., Xu, M.H., 2015. Effects of existing energy saving and air pollution control devices on mercury removal in coal-fired power plants. Fuel Process. Technol. 131, 99–108, 2015.