Analysis of the Influence of Urban Innovation Index on Urban Carbon Emission Intensity in the Context of "Carbon Neutrality"

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Abstract. In the current context of global efforts towards carbon neutrality, the reduction of carbon emissions has emerged as a prevalent and pressing trend. Governments worldwide are vigorously investing in the development of low-carbon technologies to address the urgent need for sustainability. This article delves into the intricate relationship between urban innovation capabilities and the intensity of carbon emissions within cities. The results unequivocally reveal a direct and positive correlation, highlighting that bolstering urban innovation capabilities leads to a notable reduction in urban carbon emission intensity. Governments across nations can achieve their carbon emissions reduction targets by prioritizing technological innovation and extending support to technology-driven enterprises. Consequently, each country should tailor its urban innovation development plans to its unique developmental stage. Elevating technological innovation levels and harnessing the scale effect of cities will create a synergy where governments, businesses, and individuals collectively promote innovation. This holistic approach is poised to further diminish carbon emission intensity and accelerate the realization of ambitious carbon emission reduction objectives.

Keywords: Carbon neutrality, urban, carbon emission intensity.

1. Introduction

As the current global carbon emissions problem intensifies, governments of various countries reached the Paris Agreement in 2015 following the 1997 Kyoto Protocol. It shows that countries are increasingly paying attention to the carbon emission problem and propose to control the temperature rise within 2°C before the end of this century. China, being a significant contributor to global carbon emissions, is responsible for approximately 28% of the world's total carbon emissions [1]. The Chinese central government has been committed to building a green and carbon-reducing economy and has made great efforts to this end. However, China currently faces challenges in achieving carbon neutrality: 1. Carbon emissions are still increasing, and the peak has not yet been reached. 2. Carbon reduction technology is immature, and the transformation cycle is short [2]. Hence, in response to this challenge, the Chinese administration introduced the 14th Five-Year Plan with a primary emphasis on energy transformation, reducing carbon emissions, and fostering the development of environmentally sustainable urban centers [3]. As a responsible emerging nation, China is actively dedicated to curbing carbon emissions. The Chinese government is resolute in its commitment to carbon reduction and is determined to integrate carbon reduction strategies into national development blueprints [4].

Empirical investigations have revealed that policies associated with carbon emission trading, economic growth, advancements in technology research, and enhanced global engagement can significantly contribute to reducing carbon dioxide emission intensity and promoting carbon emissions reduction [5]. Urban green development and urban innovation capabilities are interconnected in a "U"-shaped pattern [6]. Environmental regulations exert a notable and positive influence on the innovation capabilities of urban areas, accompanied by significant positive spatial ripple effects [7]. Smart city construction has a positive correlation with urban innovation capabilities [8]. In the current "double carbon" context, research has found that The advancement of digital financial services has reduced carbon emission intensity [9], and technological progress will have a crucial role in decreasing the intensity of carbon emissions [10]. Furthermore, changes in energy

structure have a favorable effect on carbon emission intensity [11]. At present, There is a limited body of literature that directly addresses the correlation between the urban innovation index and urban carbon emission intensity.

Hence, this research endeavors to delve deep into the intricate interplay between the urban innovation index (UII) and urban carbon emission intensity (UCEI). Moreover, it seeks to unravel the multifaceted impact of urban innovation and several other key factors on UCEI. Employing the technique of multiple regression analysis, this study utilizes China's prefecture-level cities as its primary units of analysis. In this analytical framework, the UII serves as the primary explanatory variable, aiming to shed light on how a city's level of innovation influences its carbon emission intensity. The UCEI, on the other hand, takes the role of the explained variable, providing crucial insights into the environmental sustainability of these urban areas. To account for potential confounding variables, the study incorporates several control variables, including urban population size, the proportion of secondary industry, and urban industrial pollution levels for each city. Through the diligent pursuit of this research, our ultimate goal is to contribute to the establishment of a robust scientific foundation for understanding the intricate relationship between urban innovation and carbon emission intensity. By doing so, we aspire to offer valuable guidance to policymakers, urban planners, and decision-makers who are entrusted with the task of steering cities towards sustainable development and fostering low-carbon economic growth. By fostering a deeper comprehension of these dynamics, we aim to facilitate informed decision-making and policy formulation, ultimately promoting the practical implementation of sustainable urban development strategies and the construction of environmentally friendly, low-carbon economies in urban areas. This research thus plays a pivotal role in addressing the pressing challenges of climate change and promoting a greener, more sustainable urban future.

2. Methodology and Data Resources

2.1. Model Settings

This research article embarks on a comprehensive exploration of the intricate connection between the Urban Innovation Index (UII) and Urban Carbon Emission Intensity (UCEI) by employing a rigorous multiple linear regression analysis. This analytical methodology offers a lens through which we can extract invaluable insights into the relationship between urban innovation levels and the intensity of carbon emissions in urban settings. The central thrust of this study is to ascertain the extent to which UII serves as a reliable predictor of UCEI, all while taking into careful account the potential influence of various other factors on carbon emissions. Our primary objective revolves around quantifying the impact of urban innovation on UCEI and deciphering the magnitude of this influence. By delving into these dynamics, the goal is to enhance comprehension of the complex relationship between innovation and carbon emissions in urban environments. This research sets out to answer pivotal questions regarding the role of urban innovation in mitigating or exacerbating carbon emissions, offering valuable insights for sustainable urban development.

2.1.1. Main variables

1. Urban Carbon Emission Intensity (UCEI): UCEI serves as the dependent variable in our regression model. It quantifies the amount of carbon emissions produced per unit of economic activity within an urban area, offering a crucial measure of environmental sustainability.

2. Urban Innovation Index (UII): This variable is at the heart of our investigation. UII represents a composite measure that encapsulates a city's innovative capacity, considering factors such as technological advancements, green initiatives, and sustainable urban development practices.

2.1.2. Control variables

1. City Population Size (CPS): The population size of a city is often associated with higher energy consumption and carbon emissions due to increased economic activities and urbanization. By

including CPS as a control variable, we aim to account for the potential impact of population size on UCEI.

2. Proportion of Secondary Industry (PSI): The proportion of secondary industry in a city's economic structure can be a significant contributor to carbon emissions. Secondary industries typically involve manufacturing and heavy industrial activities that may produce substantial carbon emissions. We include PSI to assess its influence on UCEI.

3. Urban Industrial Pollution (UIP): UIP represents the level of industrial pollution within an urban area. This variable helps us control for the impact of pollution generated by industrial processes on UCEI.

2.1.3. Regression Model

The model is constructed as follows:

$$\mathrm{UCEI} = \alpha_0 + \alpha_1 \mathrm{UII} + \alpha_2 \mathrm{CPS} + \alpha_3 \mathrm{PSI} + \alpha_4 \mathrm{UIP} + \varepsilon \quad (1)$$

In this model, α_0 represents the intercept, while α_1, α_2, α_3, and α_4 represent the regression coefficients associated with UII, CPS, PSI, and UIP, respectively. ε accounts for the error term in our model.

By analyzing the relationships between these variables and employing statistical techniques, we aim to uncover valuable insights that can inform urban planning and policymaking to foster sustainable and low-carbon urban development. This research contributes to our broader understanding of the pivotal role urban innovation plays in mitigating the adverse effects of climate change.

2.2. Variable Description and Data Source

The academic quantification of Urban Carbon Emission Intensity (UCEI) hinges on a precise calculation method. It is computed by dividing the total urban carbon emissions, measured in metric tons, by the corresponding regional Gross Domestic Product (GDP), which is expressed in 100 million yuan. This article employs this specific ratio as the primary metric to gauge and evaluate urban carbon emission intensity. In this metric, the resulting unit of measurement is expressed as tons per 100 million yuan of GDP. This approach offers a standardized way to understand the environmental impact of economic activities within urban areas. By expressing carbon emissions in relation to economic output, it enables researchers and policymakers to identify trends, make cross-city comparisons, and assess the efficiency of carbon emission reduction strategies. This measurement is instrumental in comprehending the complex connection between economic growth and carbon emissions in the context of urban sustainability.

For the assessment of Urban Innovation Index (UII) in this study, a specific measurement index has been chosen. The UII selected for this research is sourced from the "China Urban and Industrial Innovation Report 2017," authored by Professor Kou Zonglai from the School of Economics at Fudan University. This index encompasses two pivotal components: the Innovation Index and the Urban Entrepreneurship Index. The Innovation Index, as a core element of UII, provides valuable insights into a city's innovative prowess. It serves as a comprehensive yardstick, considering various facets of innovation, research, and development within urban environments. This index offers a relative value, where a smaller score corresponds to a city with a stronger and more robust culture of innovation. Additionally, the Urban Entrepreneurship Index, as part of UII, delves into the entrepreneurial spirit and activities within urban areas. It evaluates factors such as business startups, entrepreneurial support systems, and the overall entrepreneurial ecosystem. Together with the Innovation Index, this multifaceted approach paints a comprehensive picture of a city's innovation landscape. Utilizing the UII from Professor Kou Zonglai's report allows this study to draw upon a credible and established framework for assessing urban innovation. The use of a relative scale for the urban innovation index

ensures that the study can make meaningful comparisons between cities, shedding light on the varying degrees of innovation strength across different urban centers in the context of this research.

Control variables. To ensure robustness, this article considers other factors that affect urban carbon emissions, including: (1) Urban population size (CPS), measured by the permanent population of each city (10,000 people). (2) The Proportion of Secondary Industry (PSI) is determined by computing the share of secondary industry's added value in each city's Gross Domestic Product (GDP) as a percentage. (3) Urban industrial pollution (UIP), measured by the amount of industrial wastewater discharged by each city (10,000 tons).

Considering data availability, this research has chosen to work with panel data encompassing a decade-long period, ranging from 2012 to 2021, sourced from 30 Chinese cities. These cities have been categorized into five regional groups: Eastern (comprising cities like Shanghai, Hangzhou, Ningbo, Nanjing, Suzhou, Fuzhou, Xiamen, Nanchang), Southern (including urban centers such as Guangzhou, Shenzhen, Kunming, Guiyang), Central (encompassing cities like Wuhan, Hefei, Changsha, Zhengzhou, Jinan), Western (encompassing cities like Taiyuan, Xi'an, Chongqing, Chengdu, Hohhot, Xining), and Northern (comprising cities like Beijing, Tianjin, Qingdao, Shijiazhuang, Shenyang, Changchun, Harbin).Data sources for all variables, except for the urban innovation index, have been meticulously derived from reliable and authoritative references such as the "China Urban Statistical Yearbook" and the "China Environmental Statistical Yearbook" spanning multiple years. To address any gaps in the dataset, a rigorous interpolation method has been employed to supplement missing data points, ensuring the completeness and accuracy of our analysis.This approach not only allows for a comprehensive examination of the relationship between UII and UCEI but also facilitates a regional comparison, shedding light on how various parts of China have fared in terms of urban carbon emissions and innovation over the specified time frame. These insights are instrumental in guiding future policies and strategies aimed at achieving sustainable and low-carbon urban development across China.

3. Empirical Analysis Results

3.1. Basic Statistical Analysis

Thirty observations over 10 years are selected for each of the above variables. Through descriptive analysis, the average value of urban carbon emission intensity (UCEI) is 9095.221, and its standard deviation is 10330. This metric provides a central point of reference, illustrating the typical carbon emission intensity levels within the urban areas under study. On the other hand, the Urban Innovation Index (UII) exhibits an average value of 196.090. However, it's worth noting that the standard deviation for UII is relatively high, standing at 338.474. This variance signifies the diversity and fluctuation in urban innovation levels across the cities in the dataset. Furthermore, the presence of a maximum value as high as 2907.851 underscores the significant disparity in innovation capabilities among these urban centers. As these metrics are presented in their raw form and are not exponential in nature, logarithmic processing has not been applied in this analysis. A critical aspect of this analysis pertains to the assessment of heteroscedasticity. The examination reveals a P-value of 0.0000, which is notably less than the conventional significance level of 0.05. This outcome suggests the presence of heteroscedasticity within the model under consideration. The data is processed with robust standard errors, and the regression equation is as follows:

$$\begin{gathered}\mathrm{UCEI} = 1264.84 - 5.10\mathrm{UII} + 11.22\mathrm{CPS} - 102.40\mathrm{PSI} + 0.07\mathrm{UIP} + \varepsilon \\ (2927.09)\quad (2.11)\qquad (1.36)\qquad\quad (63.02)\qquad (0.05)\end{gathered} \tag{2}$$

Conducting a comprehensive correlation test within the model has yielded significant insights. Notably, it is evident that the intensity of carbon emissions exhibits a meaningful and statistically significant correlation with the Urban Innovation Index, with a coefficient value of 0.225. This

positive correlation highlights the relationship between urban innovation and carbon emission intensity, suggesting that as urban innovation levels increase, there tends to be a corresponding decrease in carbon emissions intensity. Another critical aspect of model evaluation involves testing for multicollinearity. This essential step ensures that the model's variables do not exhibit high levels of intercorrelation, which could skew the results. The findings from the multicollinearity test are satisfactory, as they reveal that the variance inflation factors (VIF) for all variables remain below the conventional threshold of 10. This outcome serves as empirical evidence affirming the absence of multicollinearity within this model, thus lending credibility to its statistical integrity. Furthermore, the Hausman test provides valuable insights into the model's suitability. With a P-value of 0.0006, which is less than the typical significance level of 0.005, the test results strongly indicate that this model is best characterized as a fixed effect model. This choice of model takes into account unobserved individual-specific effects, offering a robust and accurate framework for analyzing the relationship between urban innovation and carbon emission intensity.

In summary, the correlation test underscores the significance of the association between urban innovation and carbon emissions intensity, providing empirical support for the model's core premise. The absence of multicollinearity safeguards the model's reliability, ensuring that the variables are independently contributing to the analysis. Lastly, the Hausman test cements the appropriateness of employing a fixed effect model, further enhancing the model's suitability for drawing meaningful conclusions regarding the impact of urban innovation on carbon emission intensity.

3.2. Fixed Effects Model Analysis

In this model, time has been selected as a fixed factor, allowing for a robust time fixed effects analysis to be conducted. The results of this analysis are presented comprehensively in Table 1. One of the standout findings from this analysis is the p-value associated with the Urban Innovation Index (UII), which registers at 0.005. This low p-value signifies a high degree of statistical significance at the 1% significance level, indicating that the influence of the Urban Innovation Index on carbon emission intensity is indeed substantial and noteworthy. In simpler terms, it reinforces the idea that changes in the Urban Innovation Index have a significant impact on carbon emission intensity, emphasizing the key role of innovation in reducing carbon emissions within urban areas.

Table 1. Fixed Effect Model

VARIABLES	UCEI
UII	-4.486***
	(1.494)
CPS	1.499
	(3.076)
PSI	-104.6
	(69.22)
UIP	0.0215
	(0.0861)
Constant	14,698***
	(5,083)
Observations	300
Number of REGION	30
R-squared	0.351

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Conversely, when examining the p-values of the control variables, a different pattern emerges. For Urban Population Size (CPS), the p-value stands at 0.630, while for the Proportion of Secondary Industry (PSI) it is 0.142, and for urban industrial pollution (UIP), it is 0.805. These relatively high p-values suggest that the impact of these control variables on carbon emission intensity is not statistically significant within this model. In essence, the analysis suggests that changes in these

control variables do not exert a substantial influence on carbon emission intensity, further highlighting the dominant role of the Urban Innovation Index in driving reductions in carbon emissions.

In summary, the time fixed effects analysis provides valuable insights into the statistical significance of the Urban Innovation Index and the control variables in relation to carbon emission intensity. These findings underscore the importance of fostering innovation as a key strategy for reducing carbon emissions within urban areas, while also highlighting the limited impact of certain control variables in this context. The regression equation is as follows:

$$\mathrm{UCEI} = 14698.48 - 4.486\mathrm{UII} + 1.499\mathrm{CPS} - 104.6\mathrm{PSI} + 0.0215\mathrm{UIP} + \varepsilon \quad (3)$$

3.3. Results

Through the above test, it can infer that there is a notable correlation between the urban innovation index and carbon emission intensity. Every time the urban innovation index increases by 1 unit, the carbon emission intensity will decrease by 4.486 units. This study demonstrates that enhancing the urban innovation index is actively helpful in reducing carbon emission intensity. Enhancing their urban innovation index can enable cities to decrease carbon emission intensity.

The primary focus of this paper centers on assessing how the urban innovation index affects carbon emission intensity. The expected goals of this article match the actual results: Enhancing the urban innovation index has a favorable effect on diminishing carbon emission intensity. The outcomes of this investigation demonstrate that Chinese municipal administrations can attain their carbon emission reduction objectives by bolstering the innovation and entrepreneurial capacities of their cities.

4. Discussion

The urban innovation index holds positive significance in diminishing carbon emission intensity. The government can promote carbon emission reduction through the following aspects, and make efforts to promote sustainable urban development and address climate change: 1. The government promotes the development of low-carbon technologies by encouraging technological innovation, such as renewable energy and energy storage technologies. 2. The government can promote green travel methods, including shared travel, non-motor vehicle travel and public transportation, which can help reduce reduce reliance on private cars and alleviate traffic congestion and air pollution problems. 3. By encouraging the growth of energy-efficient technologies, the administration can reduce energy consumption in cities, thereby reducing carbon emissions. 4. the government can formulate relevant laws and regulations to constrain various social entities and individuals to reduce carbon emissions. 5. The government encourages production companies to use clean energy and clean production methods to reduce carbon emissions during the production process. 6. The government plays a key role in urban planning and construction. Sustainable urban design is key to reducing carbon emissions, and governments can encourage the development of green buildings, smart transportation systems and greening projects through urban planning policies. These initiatives not only help improve the quality of urban life but also reduce carbon emissions. 7. The government can support carbon pricing and carbon market mechanisms. The formation of a carbon market can incentivize companies to reduce carbon emissions, while also providing funds for governments to support carbon emission reduction projects. A carbon tax or carbon trading system can effectively internalize the cost of carbon emissions and incentivize businesses and individuals to take more environmentally friendly actions. Companies can proactively embrace social responsibilities, establish relevant carbon emission reduction objectives, and intensify their efforts in researching and developing technologies for carbon emissions reduction to realize the aim of decreasing carbon emissions. At the individual level, we can enhance the public awareness of carbon reduction by strengthening the publicity of carbon emission

reduction knowledge, and we can also actively participate in voluntary activities related to carbon emission reduction. Everyone can adopt simple lifestyle changes such as reducing energy consumption, reducing waste generation, supporting sustainable consumption and more. Collective actions by individuals can have a huge impact and move society towards carbon reduction goals.

At present, as the world's attention to climate issues continues to increase, carbon emission reduction has become urgent. Looking to the future, there are many innovative technologies and measures that can help reduce carbon emissions. Firstly, the development of technologies such as electric vehicles can reduce vehicle exhaust emissions. In the field of industrial manufacturing, the emergence of new concepts such as intelligent manufacturing will further stimulate advancements in production efficiency and efficiency in energy utilization, leading to diminished energy usage and carbon emissions. Secondly, clean energy technologies are gradually maturing, and the cost of use is gradually decreasing. In the near future, it will replace traditional non-renewable high-carbon energy, thereby reducing the energy industry's dependence on carbon emissions. In addition, governments of various countries have jointly addressed climate issues by strengthening international cooperation. Continuous international cooperation will foster the exchange of new technologies and facilitate the implementation of carbon emission reduction goals. However, in order to achieve the objective of carbon emissions reduction by the end of this century, more practical actions and firm beliefs are needed. Only with global joint efforts can we achieve our carbon emission reduction goals as soon as possible and usher in a clean and sustainable future.

5. Conclusion

In the present context of carbon emission reduction, a positive correlation exists between the enhancement of urban innovation capabilities and the mitigation of carbon emissions. These high-carbon-emitting cities are also often cities with strong innovation capabilities. These cities often have developed technology industries, such as artificial intelligence, new energy technology, biotechnology, etc. The active innovation activities in these industries have greatly promoted the enhancement of urban innovation capabilities. On the other hand, cities with strong innovation capabilities also tend to develop greener and more sustainable industries. This means that while the carbon intensity of certain industries may be higher, overall, the carbon intensity of these cities may be declining. Therefore, we cannot simply regard carbon emission intensity as negatively related to urban innovation capabilities. For a city, improving innovation capabilities does not mean sacrificing environmental protection. Conversely, innovation can serve as a crucial mechanism for curbing carbon emissions and advancing sustainable development. The government can achieve carbon emission reduction goals by encouraging technological innovation and supporting technology-based enterprises.

Increased urban innovation not only helps reduce carbon emissions but can also bring many other positive impacts. First, improving a city’s innovation capabilities can promote economic growth to a certain extent. Innovation-driven industrial and technological innovation can attract investment, create jobs, and bring more income and tax revenue to the city, thereby improving the city's overall economic level. Secondly, the enhancement of urban innovation will also help improve the quality of life of residents. New technologies and innovative solutions can increase the efficiency of cities' infrastructure and improve transportation, energy use and environmental management, thereby providing more convenient, cleaner and livable urban environments. This is critical to attracting talent, improving resident satisfaction and promoting cultural and social development. In addition, the improvement of urban innovation will also contribute to the city's international competitiveness. Cities with high innovative capabilities are more likely to emerge in the global economy, attract international enterprises and investment, and become centers of international exchange and cooperation. This will bring more international opportunities to the city, promote cross-border cooperation, accelerate the spread of knowledge and technology, and further enhance the city's innovation level. Urban innovation not only plays a positive role in reducing carbon emission

intensity, but also contributes to economic development, improving residents' lives, and enhancing international competitiveness. Therefore, governments, businesses and society should work together to encourage and support innovative activities in cities to achieve the goals of sustainable development and create a better future for our cities and the planet.

In summary, this research not only confirms the existence of a substantial correlation between urban innovation and carbon emission intensity but also highlights the tangible benefits of enhancing the urban innovation index. It underscores the pivotal role that innovation can play in realizing sustainability goals and reducing the carbon footprint of urban areas. These insights provide valuable guidance for policymakers and urban planners, encouraging them to prioritize and invest in initiatives that foster innovation and entrepreneurial ecosystems within their cities. By doing so, they can not only achieve their carbon emission reduction targets but also unlock a host of additional economic, social, and environmental benefits that contribute to the well-being and prosperity of their communities and the broader global effort to combat climate change.

References

[1] Liu, Z., Deng, Z., He, G., Wang, H., Zhang, X., Lin, J., ... & Liang, X. (2022). Challenges and opportunities for carbon neutrality in China. Nature Reviews Earth & Environment, 3 (2), 141 - 155.

[2] Zhao, X., Ma, X., Chen, B., Shang, Y., & Song, M. (2022). Challenges toward carbon neutrality in China: Strategies and countermeasures. Resources, Conservation and Recycling, 176, 105959.

[3] Hepburn, C., Qi, Y., Stern, N., Ward, B., Xie, C., & Zenghelis, D. (2021). Towards carbon neutrality and China's 14th Five-Year Plan: Clean energy transition, sustainable urban development, and investment priorities. Environmental Science and Ecotechnology, 8, 100130.

[4] Li, J., & Li, S. (2020). Energy investment, economic growth and carbon emissions in China—Empirical analysis based on spatial Durbin model. Energy Policy, 140, 111425.

[5] Xuan, D., Ma, X., & Shang, Y. (2020). Can China’s policy of carbon emission trading promote carbon emission reduction? Journal of cleaner production, 270, 122383.

[6] Li, G., & Jiang, X. (2020). Green development, talent agglomeration and urban innovation enhancement—a study based on the Yangtze River Delta urban agglomeration. Journal of Anhui University (Philosophy and Social Sciences Edition), 3.

[7] Zhou, R., Zhang, Y., & Gao, X. (2021). The spatial interaction effect of environmental regulation on urban innovation capacity: Empirical evidence from China. International Journal of Environmental Research and Public Health, 18 (9), 4470.

[8] Chu, J., & Zhong A. (2021). Research on the impact of smart city construction on the improvement of urban innovation. E-Government, 18 (4), 16 - 29.

[9] Yao, L., & Zhang, M. (2023). Research on the impact of digital finance on carbon emission intensity under the "double carbon" goal. Journal of Jiangsu Ocean University (Humanities and Social Sciences Edition), 2023, 21 (04): 120 - 131.

[10] Zhang, F., Deng, X., Phillips, F., Fang, C., & Wang, C. (2020). Impacts of industrial structure and technical progress on carbon emission intensity: Evidence from 281 cities in China. Technological Forecasting and Social Change, 154, 119949.

[11] Dong, F., Yu, B., Hadachin, T., Dai, Y., Wang, Y., Zhang, S., & Long, R. (2018). Drivers of carbon emission intensity change in China. Resources, Conservation and Recycling, 129, 187 - 201.