BUKTI PROSES REVIEW SUSTAINABILITY (2) 2022

Tourism Village Carbon Footprint after COVID-19 Pandemic: A Challenge to Sustainability

Semarang, 9 January 2022.

Editor in Chief
Sustainability – MDPI

Dear Sir,
We would like to submit our manuscript entitled "Tourism Village Carbon Footprint after Covid-19 Pandemic: a Challenge to Sustainability" to "Sustainability– MDPI".

Tourism industry is the most significant global GHGs (Green House Gases) contributor which especially produced by tourism activities. Therefore, several action had been taken to reduce CO_2 emissions and maintaining sustainable development. Since the Tourism Village in Indonesia also became an "actor of carbon emission contributor" and also a "victim of Covid-19 pandemic impact", the low-carbon tourism necessary needs to be implemented to achieve the sustainable tourism villages. Our research aimed to study the carbon footprint of solid waste produced by visitors, population, and buildings in the 7 certified Tourism Villages in Central Java Province (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon Tourism Villages) and Special Region of Yogyakarta Province (Pentingsari Tourism Village) which are famous and popular tourism destinations in Indonesia. Our research found that Dieng Kulon Tourism Village had the biggest carbon emissions from all sources (solid waste produced by visitors and population and also buildings). It was Candirejo Tourism Village that had the lowest solid waste carbon emission produced by visitors before Covid-19 pandemic as well as by population. During Covid-19 pandemic, Kandri Tourism Village found as the lowest contributor of solid waste carbon emission produced by visitors while Samiran Tourism Village.

There is no doubt that the sustainability of Tourism Village is a key to raise the income as well as to obtain the cleaner, and healthier of Tourism Village. Hence, Tourism Villages should lead economic recovery of rural communities after Covid-19 pandemic to achieve sustainable development goals by carbon emission reduction action. Finally, we proposed the "The Low-Carbon Sustainable Tourism Village Model" to answer the challenge of sustainability.

The "Sustainability – MDPI" is a reputable journal and has broader readers. Therefore, we believe to publish our manuscript here and we hope that our submission will become advantage in the sustainability, especially in carbon footprint of tourism village studies.

This manuscript has not been previously published and is not under consideration in the same or substantially similar form in any other peer-reviewed media.

Thank you very much. We would like to hear from you about our submission.

<div align="center">Sincerely,</div>

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Article type	Article
Title	Tourism Village Carbon Footprint after Covid-19 Pandemic: A Challenge to Sustainability
Journal	*Sustainability* (https://www.mdpi.com/journal/sustainability)

Abstract

The tourism industry is the most significant global GHGs (Green House Gases) contributor, which is often specifically produced by exploratory activities. This leads to the performance of several actions, to reduce CO2 emissions and maintain sustainable development. Since the Indonesian Tourism Village is a "carbon emission contributor and Covid-19 pandemic impact victim", the low-carbon exploration should be necessarily implemented to achieve sustainability. Therefore, this study aims to determine the carbon footprint of solid waste produced by visitors, population, and buildings within 7 certified Tourism Villages in Central Java (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon) and Special Region of Yogyakarta (Pentingsari) Provinces, Indonesia. This was conducted through a mix-method containing quantitative and analytical techniques. The quantitative method was conducted through a field survey to 7 Tourism Villages, to obtain and analyze data on the population, infrastructures, situations, and environments. Meanwhile, the analytical method was conducted by calculating the carbon footprint of solid waste and buildings, produced by 7 Tourism Villages. The results showed that Dieng Kulon had the biggest carbon emissions from all sources (solid waste produced by visitors, population, and buildings). Also, Candirejo had the lowest solid waste emission produced by the visitors and population, before the impact of the pandemic. During the Covid-19 period, Kandri and Samiran were observed as the lowest contributors of solid-waste carbon emission produced by visitors and buildings, respectively. This indicated that the sustainability of Tourism Village helped in increasing income, as well as obtaining a cleaner and healthier environment. After the pandemic period, these villages should subsequently lead the economic recovery of rural communities, to achieve sustainable development goals through the reduction of carbon emission. In addition, the "The Low-Carbon Sustainable Tourism Village Model" was proposed by this study to answer the challenge of sustainability.
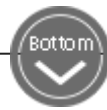
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Abstract: The tourism industry is the most significant global GHGs (Green House Gases) contributor, which is often specifically produced by exploratory activities. This leads to the performance of several actions, to reduce CO2 emissions and maintain sustainable development. Since the Indonesian Tourism Village is a "carbon emission contributor and Covid-19 pandemic impact victim", the low-carbon exploration should be necessarily implemented to achieve sustainability. Therefore, this study aims to determine the carbon footprint of solid waste produced by visitors, population, and buildings within 7 certified Tourism Villages in Central Java (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon) and Special Region of Yogyakarta (Pentingsari) Provinces, Indonesia. This was conducted through a mix-method containing quantitative and analytical techniques. The quantitative method was conducted through a field survey to 7 Tourism Villages, to obtain and analyze data on the population, infrastructures, situations, and environments. Meanwhile, the analytical method was conducted by calculating the carbon footprint of solid waste and buildings, produced by 7 Tourism Villages. The results showed that Dieng Kulon had the biggest carbon emissions from all sources (solid waste produced by visitors, population, and buildings). Also, Candirejo had the lowest solid waste emission produced by the visitors and population, before the impact of the pandemic. During the Covid-19 period, Kandri and Samiran were observed as the lowest contributors of solid-waste carbon emission produced by visitors and buildings, respectively. This indicated that the sustainability of Tourism Village helped in increasing income, as well as obtaining a cleaner and healthier environment. After the pandemic period, these villages should subsequently lead the economic recovery of rural communities, to achieve sustainable development goals through the reduction of carbon emission. In addition, the "The Low-Carbon Sustainable Tourism Village Model" was proposed by this study to answer the challenge of sustainability.

Keywords	Tourism Village, carbon footprint and emission, solid waste, building, Covid-19, sustainability.
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Response to Reviewer 1 Comments
(Round 1)

We appreciate and thank to the very valuable comments and advises of the Reviewer 1. We also would like to deliver our discussion and comments from our side which will be explained as follow.

The text presents the result of an interesting and methodologically well-developed research. The research has a well-presented focus and brings the necessary data for a thorough analysis. The methodology is clearly presented. The results were exhaustively presented, making the validity of the proposal clear. The discussion of the data with the related literature is incipient. It is also necessary that the authors dedicate themselves to exploring the theoretical and practical implications of the proposed model. The conclusion is still incipient.

> **Response:**
> We thank to the valuable comments and advises of Reviewer 1. Since the conclusion is still incipient we had developed the discussion part and revised the conclusion to be richer, wider, and clearer.

Response to Reviewer 2 Comments

We appreciate and thank the very valuable comments and advice of Reviewer 2. We also would like to deliver our discussion and comments from our side which will be explained as follow.

The whole concept of the study is not clear. For example, why should we include Dieng Kulon? It stands out as it is much bigger than other villages. Moreover, the villages are described only by the number of population, and emissions, etc. - only quantitative characteristics. We do not know whether they have any waste management system or sewage treatment plants. Moreover, we do not know much about their tourist capacity - what was the accommodation base occupancy rate before covid-19?

Response:

1. The whole concept of the study is not clear – **Response:** We had tried to explain the whole concept of the study as follow. The tourism industry plays an important role in climate change, based on being a "carbon emission contributor and victim of the Covid-19 pandemic impact". Since the contribution of tourism industry become greater year to year, it is important to reduce carbon footprint of Tourism Village, especially the 7 Tourism Villages considered in this study as the most popular and certified Tourism Villages in Central Java Province and Special Region of Yogyakarta Province. It is also obvious that Covid-19 pandemic has impact of zero or very low visitor arrivals which also make the hard impact to the 7 Tourism Villages. Hence, this study aimed to determine the carbon footprint of solid waste produced by the visitors, population, and also carbon footprint of buildings within 7 Tourism Villages in Central Java and Yogyakarta Special Region Provinces, Indonesia, before and after Covid-19 pandemic to be analyzed and get a suitable model for better future of Tourism Village to have good economic impact as well as its green and sustainable characteristic as advantage. According to your advice, we have reconstructed the paragraphs to become clearer.

2. For example, why should we include Dieng Kulon? It stands out as it is much bigger than other villages – **Response:** We included Dieng Kulon since it is a famous tourism destination in Indonesia that has high visitor domestic and foreign arrivals. Dieng Kulon is not the biggest among the 7 Tourisme Villages, in population or in area context. It is explained by Table 3 that Dieng Kulon has 5,300 population (the biggest is Lerep that has 9000 population) and area of 210 km^2 (the biggest is Lerep that has area of 682 km^2). It should also be noted that Dieng Kulon has very big visitors also because it has not implemented limitation of visitor number such as other 6 Tourism Villages that offer 'packages' tourism and entertainment). We had made explanation about this fact in Chapter 3, Table 4.

3. Moreover, the villages are described only by the number of population, and emissions, etc. - only quantitative characteristics – **Response:** Despite of quantitative characteristic, we also explained the topography of each village in the first paragraph of Section 3. However, due to Reviewer 2's advice, we added Table 3 to describe the venues and products of the 7 Tourism Villages.

The model, presented as one of the main contributions of the study, is not fully described. Are the colours meaningful? Why do you have "carbon/CO2 emissions" and "tourism village" twice in the model. In my opinion in current shape the model is just a bunch of randomly picked factors and concepts and it should be rebuild. What about the arrows in the model? Do they mean anything? Causality?

Response: According to Reviewer 2's advice, we have revised and rebuilt the model (Figure 5) and also sub-section 4.2 to be clearer. Please find the revised paragraphs in the revised manuscript. Thank you for letting us improve and rebuilt the model.

Abstract: the names of the villages are not familiar to non-Indonesian readers. Therefore, to show the findings in a more appealing way, there should be information on key characteristics of them.

Response: Thank you for reminding us about this important aspect. Hence, we change Figure 2 with photographs of each Tourism Village together with the map. We had explained the topography of each

village in the first paragraph of Section 3. To enrich the description of the 7 Tourism Villages, we added Table 3 to describe the venues and products of the 7 Tourism Villages.

This indicated that the high number of carbon emissions was due to the large volume of solid waste produced by the visitors and the population. – it is too obvious to even write about it! If Dieng Kulon was excluded the results would be more insightful.

Response: As a matter of fact, in those sub-section, we meant to explain the difference volume of solid waste produced by the visitors and population in those 7 Tourism Villages. Surely, the big number of visitors and population will produce big volume of solid waste. Therefore, we tried to add explanation in the first paragraph after Figure 3.

Some phrases sound bizzare or are hard to comprehend – examples: The impact of this pandemic is found to be devastating for rural communities, specifically tourism villages, leading to the necessary implementation of low-carbon exploratory activities, to achieve sustainability (lines: 133-134) – I do not understand how COVID-19 coerced low-carbon solutions.

Response: The impact of this pandemic is found to be devastating for rural communities, specifically tourism villages, leading to the necessary implementation of low-carbon exploratory activities, to achieve sustainability. We had revised by added sentences "It is happened because of the tourism activities limitation by regulation during Covid-19 pandemic had made the Tourism Villages had low or even zero visitors and activities. The low tourism activities in Tourism Villages had produced low carbon footprint that is a 'blessing in disguise'".

Low demand of tourist arrivals and sectors (131)- what is meant by this phrase?

Response: low demand of tourist arrivals and sectors was caused by the tourism activities limitation by regulation during Covid-19 pandemic (see "Also, the pandemic affected the arrival of tourists, which declined 74% of approximately 1 billion trips within January-December 2020 [15]").

However, the concern of a low-carbon sustainable Tourism Village has not been completely implemented (146) – concern or concept?

Response: The sentence has been revised to become "However, the concept of a low-carbon sustainable Tourism Village has not been completely implemented".

Based on this study, a big question was observed regarding (301) – bizarre phrase - how do you observe a question?

Response: The sentence has been revised to become "Based on this study, it is interesting to analyze the carbon emission produced by the population of both Dieng Kulon and Nusa Penida Island (Table 7)".

Response to Reviewer 3 Comments
(Round 1)

We appreciate and thank the very valuable comments and advice of Reviewer 3. We also would like to deliver our discussion and comments from our side which will be explained as follow.

Dear authors, I found the method and results presented in the manuscript with interest and I will be very pleased to see a revised version of it published in its final form in the journal Sustainability. My comments are mainly concern with the way work is presented and less with the contents, though I would like to see them considered in the final version of the manuscript.

> **Response:** We thank very much for your advice to improve the quality and delivery of our manuscript. We have made several revision, reconstruction, and rebuilt to fulfil the Reviewers' advice.

Affiliations are repeated several times (between lines 6 and 22). It is sufficient to mention this affiliation only once, assigning the same number to each author.

> **Response:** We actually followed the template of the journal (Sustainability). The affiliation may be mentioned several times, but each person had their own institutional email. However, if the Editor has another suggestion, we are ready to adjust.

In Table 1 the abbreviation EF (Emission Factor) must be expressed in full. These must be the most complete as possible, because figures should be legible without the need to see the main text.

> **Response:** We have revised the EF to become Emission Factor for Table 1's title

Figures 1 and 2 need to be thoroughly revised. For one thing, figure 1 should present a smaller scale regional context in order to frame the regional location of the country (Indonesia) and the island of Java. In Figure 1 the photographs of the villages are not readable, so I suggest that they be removed, with only the points where they are located represented. As for figure 2, it is not clear what its purpose is. The limits and names present in the images may confuse the reader, not bringing much information related to the work. Therefore, I suggest to replace this figure by another composite figure, with the photographs of each village, something that the authors tried to add in figure 1. These photographs should be of good quality and size that allows its reading. Titles should be avoided (as in figure 2, with a pink background).
In this sense, titles of figures 1 and 2 should be:
Figure 1. location of Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, Dieng Kulon, and Pentingsari Tourism Villages in Central Java and Yogyakarta Special Region Provinces, Indonesia.
Figure 2: Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, Dieng Kulon, and Pentingsari Tourism Villages in Central Java and Yogyakarta Special Region Provinces, Indonesia.

> **Response:** Thank you very much for detailed advice for us to improve Figure 1 and Figure 2. We have revised those figures as your advice.

I suggest that "7 tourism villages" used in the titles of tables 3 to 11 and figures 3 and 4 should be revised. Even though the names of the villages appear in these tables and figures, it is important to reinforce that the data represented are for the 7 specific tourism villages considered for the study presented here. Thus, it is suggested something like "... of the seven Tourism Villages in Indonesia considered in this study..."

> **Response:** We have revised those tables and figures as your advice.

The title of Figure 5 would look better as: Figure 5. Schematic model proposal for the "low-carbon sustainable Tourism Village". Furthermore, the use and differentiation of colors in the scheme is not clear. These colors should have a meaning (by type of input or action).

Response: We have revised the Figure 5's title. The model has also been rebuilt and the explanation involved the colours used in the model.

Conclusions - I think that this chapter is too short, presenting itself more as a summary of what has been said above than true conclusions. I suggest discussing, for example, the specific reality of Indonesia for the existence of this type of tourism and whether or not the results obtained can be extrapolated to other regions of the world with similar characteristics.

Response:
We thank to the valuable advice for Conclusion reconstruction. We had revised by reconstructing this Section.

Journal	Sustainability (https://www.mdpi.com/journal/sustainability) (ISSN 2071-1050)
Manuscript ID	sustainability-1569817
Type	Article
Title	Tourism Village Carbon Footprint after Covid-19 Pandemic: A Challenge to Sustainability
Authors	Rr. M. I. Retno Susilorini * , Amrizarois Ismail , BY. Arya Wastunimpuna , Dhiyan Krishna Wardhani , Laurel Lia Nola Prameswari , Ardhito Hayyu Amasto , Agus Suryono

| Abstract | The tourism industry is the most significant global GHGs (Green House Gases) contributor, which is often specifically produced by exploratory activities. This leads to the performance of several actions, to reduce CO2 emissions and maintain sustainable development. Since the Indonesian Tourism Village is a "carbon emission contributor and Covid-19 pandemic impact victim", the low-carbon exploration should be necessarily implemented to achieve sustainability. Therefore, this study aims to determine the carbon footprint of solid waste produced by visitors, population, and buildings within 7 certified Tourism Villages in Central Java (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon) and Special Region of Yogyakarta (Pentingsari) Provinces, Indonesia. This was conducted through a mix-method containing quantitative and analytical techniques. The quantitative method was conducted through a field survey to 7 Tourism Villages, to obtain and analyze data on the population, infrastructures, situations, and environments. Meanwhile, the analytical method was conducted by calculating the carbon footprint of solid waste and buildings, produced by 7 Tourism Villages. The results showed that Dieng Kulon had the biggest carbon emissions from all sources (solid waste produced by visitors, population, and buildings). Also, Candirejo had the lowest solid waste emission produced by the visitors and population, before the impact of the pandemic. During the Covid-19 period, Kandri and Samiran were observed as the lowest contributors of solid-waste carbon emission produced by visitors and buildings, respectively. This indicated that the sustainability of Tourism Village helped in increasing income, as well as obtaining a cleaner and healthier environment. After the pandemic period, these villages should subsequently lead the economic recovery of rural communities, to achieve sustainable development goals through the reduction of carbon emission. In addition, the "The Low-Carbon Sustainable Tourism Village Model" was proposed by this study to answer the challenge of sustainability. |

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	Yes	Can be improved	Must be improved	Not applicable
Is the content succinctly described and contextualized with respect to previous and present theoretical background and empirical research (if applicable) on the topic?	(x)	( )	( )	( )
Are the research design, questions, hypotheses and methods clearly stated?	(x)	( )	( )	( )
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Are the conclusions thoroughly supported by the results presented in the article or referenced in secondary literature?	( )	( )	( )	( )

Comments and Suggestions for Authors

The revised version of the manuscript is a significant improvement. The paper can be published in this version.

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CERTIFICATE OF ACCEPTANCE

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Authored by:

Rr. M. I. Retno Susilorini; Amrizarois Ismail; BY. Arya Wastunimpuna; Dhiyan Krishna Wardhani; Laurel Lia Nola Prameswari; Ardhito Hayyu Amasto; Agus Suryono

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Article type	Article
Title	Tourism Village Carbon Footprint after Covid-19 Pandemic: A Challenge to Sustainability
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Reviewer 3   Review Report (Round 1) (/user/manuscripts/review/23964878?report=17161152)

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Article

Tourism Village Carbon Footprint after COVID-19 Pandemic: A Challenge to Sustainability

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Abstract: The tourism industry is the most significant global Green House Gases (GHGs) contributor, which is often specifically produced by exploratory activities. This leads to the performance of several actions to reduce carbon emissions and maintain sustainable development. Since the Indonesian Tourism Village is a "carbon emission contributor and COVID-19 pandemic impact victim", the low-carbon exploration should be necessarily implemented to achieve sustainability. Therefore, this study aims to determine the carbon footprint of solid waste produced by visitors, population, and buildings within seven certified Tourism Villages in Central Java (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon) and Special Region of Yogyakarta (Pentingsari) Provinces, Indonesia. This was conducted through a mixed method containing quantitative and analytical techniques. The quantitative method was conducted through a field survey of seven Tourism Villages to obtain and analyze data on the population, infrastructures, situations, and environments. Meanwhile, the analytical method was conducted by calculating the carbon footprint of solid waste and buildings produced by seven Tourism Villages. The results showed that Dieng Kulon had the biggest CO_2 emissions from all sources (solid waste produced by visitors, population, and buildings). In addition, Candirejo had the lowest solid waste emission produced by visitors and the population before the impact of the pandemic. During the COVID-19 period, Kandri and Samiran were observed as the lowest contributors of solid-waste CO_2 emission produced by visitors and buildings, respectively. This indicated that the sustainability of Tourism Villages helped in increasing income as well as obtaining a cleaner and healthier environment. After the pandemic period, these villages should subsequently lead the economic recovery of rural communities to achieve sustainable development goals through the reduction of CO_2 emission. In addition, the "The Low-Carbon Sustainable Tourism Village Model" was proposed by this study to answer the challenge of sustainability.

Keywords: tourism village; carbon footprint; CO_2 emission; solid waste; building; COVID-19; sustainability

1. Introduction

Climate change has been a devastating phenomenon over two centuries, as reported by the IPCC (Intergovernmental Panel on Climate Change) [1], which stated that the global surface temperature alteration was averaged at $0.99°$ between 1850–1900, with a $0.5°$ increase also observed until 1950. However, a significant increase from 1.09–$1.3°$ was observed between 2011–2020, due to the contribution of GHGs (Green House Gases), specifically CO_2, and aerosols. This indicates that climate change has threatened global cultures, lands, and livelihoods [2]. Therefore, action should be initiated to promote

climate change and disaster risk reduction, as well as decrease the emission of CO_2 for sustainable development.

The minimization of climatic change impacts is found to be very necessary, specifically CO_2 emission reduction and implementation of a low-carbon footprint policy. Furthermore, several global agreements have been ratified in responding to these impacts, such as the Sendai Framework for Disaster Risk Reduction (March 2015; UNISDR 2015), Paris Agreement (United Nations Framework Convention on Climate Change, UNFCCC, 2015), and the SDGs (Sustainable Development Goals) agreed upon by 193 countries (UNGA 2015). These global policy agreements have helped in strengthening all countries to prepare, adapt, and mitigate the impact of climate change towards sustainable development goals [3]. One of several countries with a strong climatic change commitment is the Republic of Indonesia, due to the signing of the Kyoto Protocol (ratified on 3 December 2004) and the Paris Agreement (ratified on 31 October 2016) on 13 July 1998 and 22 April 2016, respectively. The role of this country in the global climatic forum is also represented by hosting the 13th Conference of Parties (COP-13), which was held in Bali on 3–4 December 2007. Moreover, several laws and regulations have been stipulated by the Indonesian Government, to implement the policy of climate change. These included Law No. 6/1994 (ratified the United Nations Framework Convention on Climate Change), Law No. 17/2004 (ratified the Kyoto Protocol and the UN Framework Convention on Climate Change), and Law No. 16/2016 (ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change).

The tourism industry plays an important role in climate change, based on being a "carbon emission contributor and victim of the COVID-19 pandemic impact". As an "actor of carbon emission contributor", this industry has significantly contributed to GHGs (Green House Gases) on a global scale. This was in line with [4,5], which stated that an increase was observed within the tourism's global carbon footprint, between 3.9–4.5 $GtCO_2$ emission in 2009–2013 (approximately 8% of global GHGs). Since this emission is being produced by tourism activities, several reduction actions should be implemented in maintaining sustainable development towards a low-carbon economy [6]. This economy has been developed towards a new concept of low-carbon tourism based on sustainability [7–10]. The carbon footprint of tourism is known as the direct emission of exploratory activities and embodiments within the tourists' purchased commodities, such as transportation, fuel, food, accommodation (hotels, guest houses, homestays, etc.), dining, recreational programs, souvenirs, and shopping [4,5]. Based on previous studies [11–13], a significant volume of CO_2 emission was produced by the tourist attractions within the heritage sites of Yogyakarta Special Region in Indonesia, as well as the Wulingyuan Scenic/Historic Interest Area (WSHIA) and Guizhou ethnic locations in China.

According to the UNWTO Barometer (September 2021), the pandemic played a 'role' in tourism as a "victim of COVID-19 impact", which greatly and globally suffered in the exploratory industry [14]. This indicated that global international tourist arrivals (overnight visitors) until July 2021 were 40% below the levels of 2020, which was 80% lower still compared to the similar pre-pandemic period in 2019. In addition, the pandemic affected the arrival of tourists, which declined 74% of approximately 1 billion trips within January–December 2020 [15]. The UNWTO subsequently stated that the impact of the COVID-19 pandemic affected "all parts of its vast value-chain," such as global economies, livelihoods, public services, and opportunities, respectively [16]. Therefore, tourism export revenues have reportedly declined to $910 billion from $1.2 trillion in 2020, which also reduced the global GDP from 1.5–2.8%. Based on several studies [17–22], the solid waste management produced by tourism activities has been investigated, as well as its carbon footprint and reduction strategies. This indicated that tourist activities had contributed 41.9–46.6% of solid waste generation per resident in Madeira Island, Portugal [18], and subsequently produced 48.21% of organic pollutants in the Nusa Penida Islands, Indonesia [20]. According to [19], proper waste management was analyzed in the tourism area of Coachella Valley, California, USA, although the distinctions between the pollutant administration

in rural and urban areas were still very important, specifically in exploratory regions [21]. These studies showed that tourism activities should be adequately managed in producing low-carbon solid waste.

Among the contributors of global GHGs, buildings are found to have highly contributed to the crisis of climate change, specifically the 'embodied' emissions from the manufacturing and processing of construction materials, as reported by [23]. This study indicated that the average share of embodied GHG was approximately 20–25% of life cycle emissions. Based on the UN Environment Program [24], the direct energy-related emissions observed from buildings was approximately 6.9 $GtCO_2$ in 2019. However, both direct and indirect emissions were observed at 10 $GtCO_2$ in the same year (approximately 28% of total global CO_2 emissions). The manufacture, transportation, and utilization of all construction materials also contributed to CO_2 emissions at approximately 3.5 $GtCO_2$ in 2019 (10% of all energy sector emissions). According to [25], the building's life cycle related to energy consumption contained several stages, namely: planning and designing, material preparations, construction, operational maintenance, and dismantlement. Among these stages, the operational maintenance and material preparations highly contributed to the emission of CO_2 at 78.05 and 20.59%, respectively.

The tourism industry in Indonesia (specifically Tourism Villages) is reportedly affected by the COVID-19 pandemic, due to the decline and low demand of tourist arrivals and sectors, as well as the closure of exploratory, attractive, and entertainment sites, respectively. The impact of this pandemic is found to be devastating for rural communities, specifically Tourism Villages, leading to the necessary implementation of low-carbon exploratory activities to achieve sustainability. This has happened because the tourism activities' limitation by regulation during the COVID-19 pandemic made the Tourism Villages have low or even zero visitors and activities. The low tourism activities in Tourism Villages produced a low carbon footprint that is a 'blessing in disguise'. However, the gradual growth of the tourism industry during the post-pandemic period is optimistically achieved.

Since the carbon emission contribution of the tourism industry becomes greater year to year, it is important to reduce carbon footprints of Tourism Villages, especially the seven Tourism Villages considered in this study as the most popular and certified Tourism Villages in Central Java Province and Special Region of Yogyakarta Province. A total of six villages (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, and Dieng Kulon) are located in Central Java, with only one (Pentingsari) in the Special Region of Yogyakarta. All these sites are found to be certified as "Sustainable Tourism Villages" by the local government, with some also being provided with several prestigious international awards. However, the concept of low-carbon sustainable tourism village have not been fully implemented yet.

It is also obvious that the COVID-19 pandemic has an impact of zero or very low visitor arrivals of those seven Tourism Villages. Hence, this study aimed to determine the carbon footprint of the Tourism Village which is produced by several exploratory activities, specifically in the utilization of energy in construction, building operation and maintenance, etc. Carbon footprints of the seven Tourism Villages are mostly contributed by the visitors and the buildings' operation and maintenance; therefore, it is important to calculate the carbon emissions before and after the COVID-19 pandemic produced by the visitors and buildings. The carbon footprints of the Tourism Villages have to be analyzed and a suitable model obtained for the future of Tourism Villages to have good economic impact as well as green and sustainable characteristics as advantages. A low-carbon sustainable Tourism Village will be implemented in the model proposed in this research, the "Low-Carbon Sustainable Tourism Village Model", which aimed to reduce the carbon footprint of exploratory sites and solve the challenges of global sustainability.

2. Methods

This study was conducted through a mixed method containing both quantitative and analytical techniques. The quantitative method was implemented through the field survey and data analysis of seven Tourism Villages (Kandri, Lerep, Samiran, Karangrejo, Candi-

rejo, Samiran, Dieng Kulon, Pentingsari), as shown in Figures 1 and 2. This survey was conducted to obtain data on the population, infrastructures, situations, and environments of Tourism Villages. Meanwhile, the analytical method was conducted by calculating the carbon footprint of buildings and the solid waste produced by these villages, as shown in Equation (1) [26],

$$E_c = EF \times V \tag{1}$$

where,

E_c = Carbon emission of solid waste (kg CO_2/kg)
EF = Emission Factor of solid waste
V = Solid waste volume
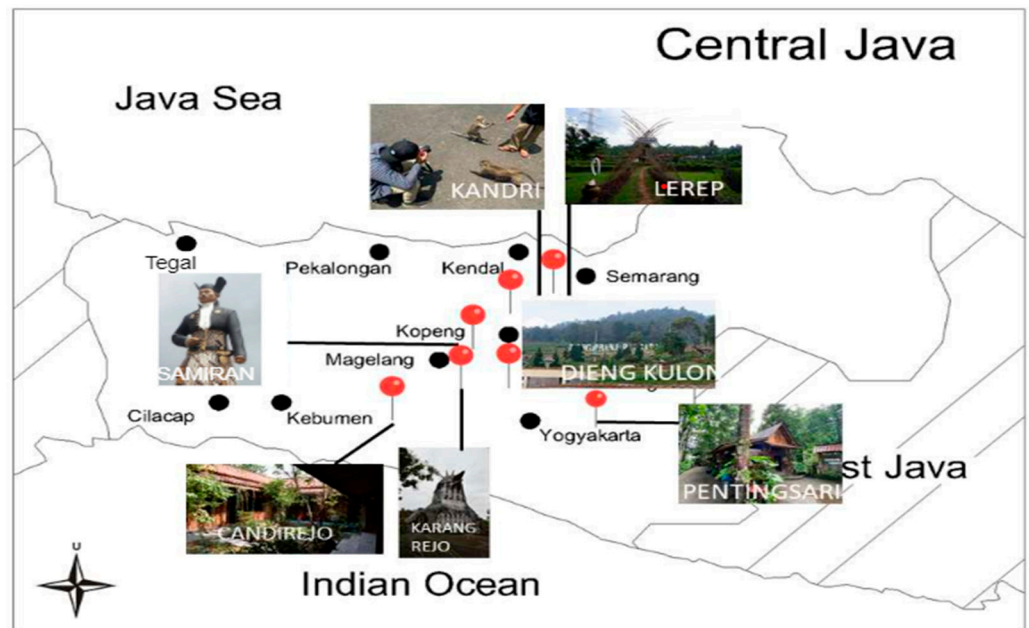
Figure 1. Location of seven Tourism Villages (Kandri, Lerep, Samiran, Karangrejo, Candirejo, Samiran, Dieng Kulon, Pentingsari) in Central Java and Yogyakarta Special Region Provinces, Indonesia.

(**a**)

Figure 2. *Cont.*

(**b**)

(**c**)

(**d**)
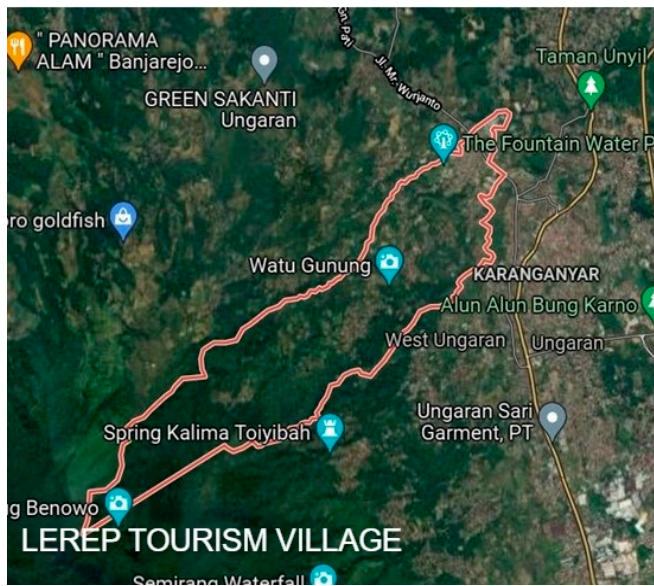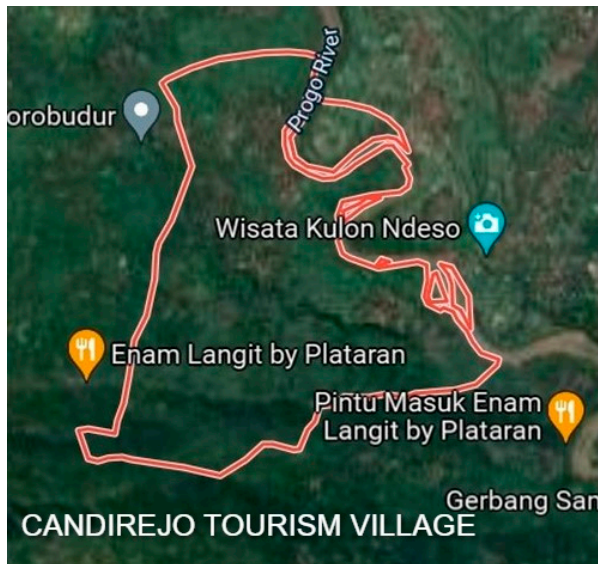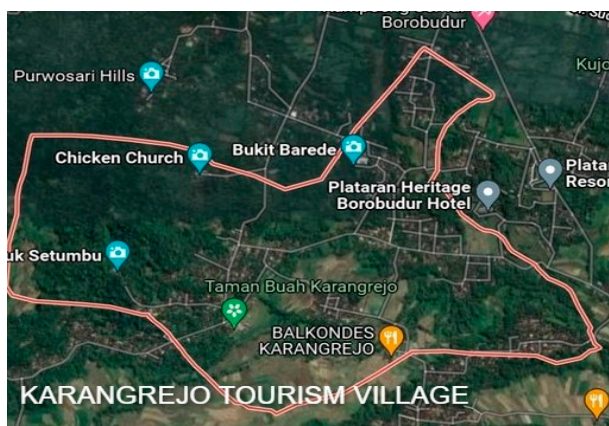
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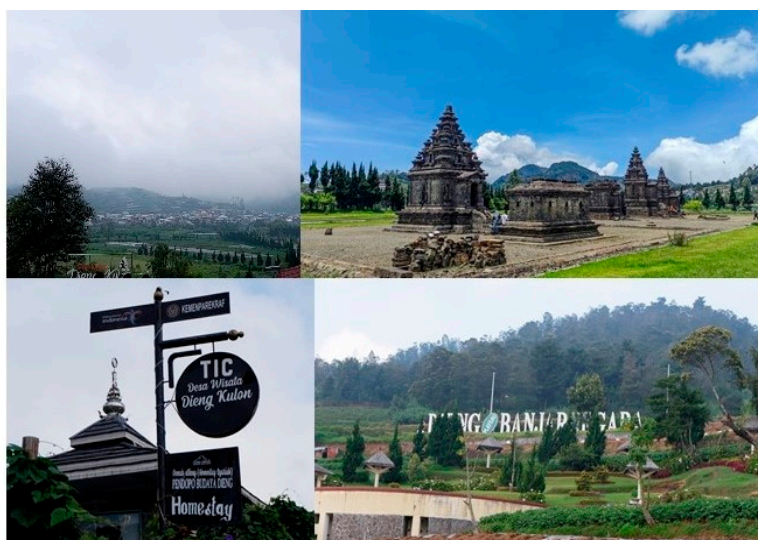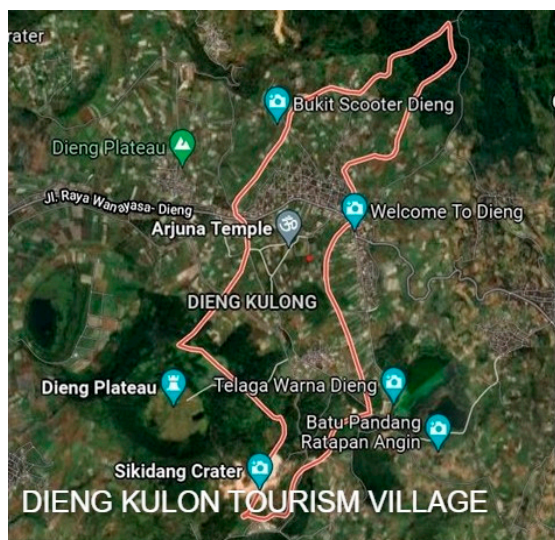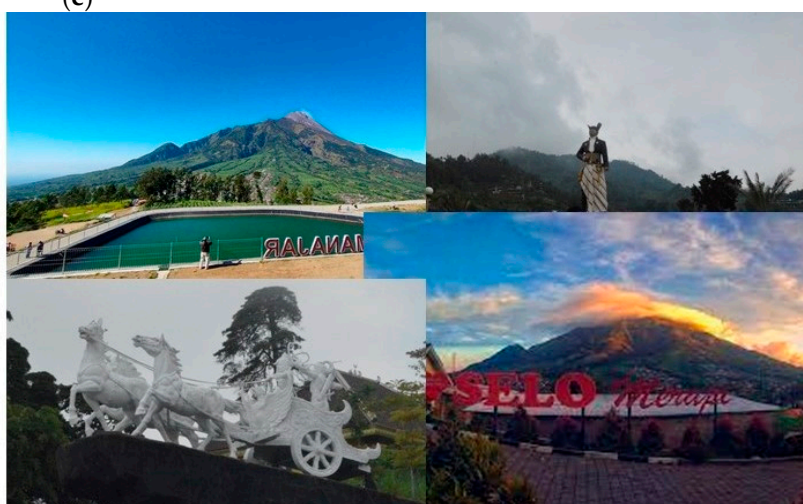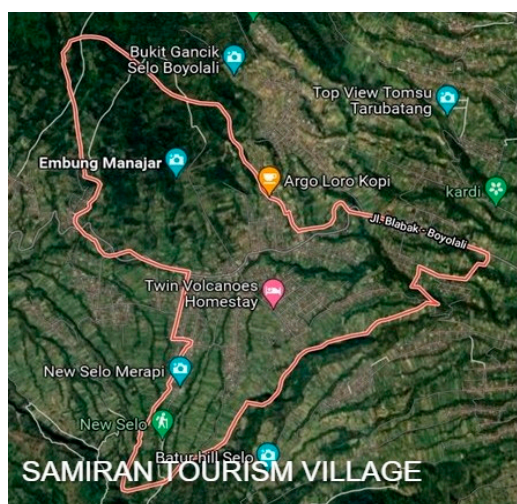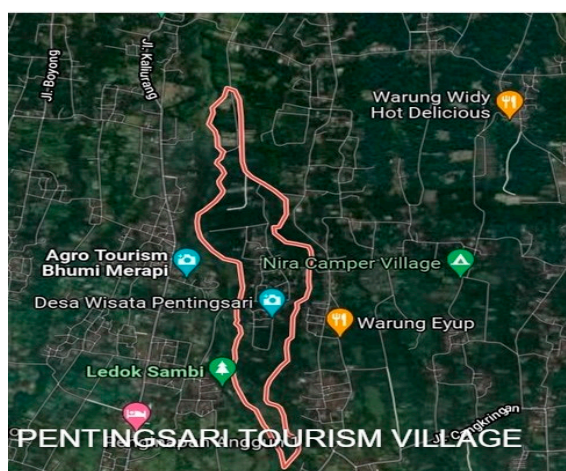
Figure 2. The seven Tourism Villages; (**a**) Kandri, (**b**) Lerep, (**c**) Karangrejo, (**d**) Candirejo, (**e**) Samiran, (**f**) Dieng Kulon, and (**g**) Pentingsari.

Based on [27,28], Emission Factor (EF) for household and individual solid wastes are shown in Tables 1 and 2, respectively.

Table 1. Emission Factor for household solid waste based on research of [27].

Subject	Emission Factor
Rural-Household-Solid Waste-Inorganic	0.668
Rural-Household-Solid Waste-Organic	0.45

Table 2. The daily solid waste production per person based on research of [28].

Solid Waste	Production per Person per Day (kg)	Production per Person per Month (30 Days) (kg)
Food	0.0232	0.696
Paper	0.0753	2.259
Plastic	0.0662	1.986
Organic	0.3305	9.915

Based on [23], the carbon emission of buildings for seven Tourism Villages was calculated using Equation (2).

$$E_c = E_{em} \times A \tag{2}$$

where,

E_c = Carbon emission of the building (kg CO_2/m^2)
EF = Embodied GHG for building = 6.7 kg CO_2/m^2
A = Building's area

The results of the analysis of carbon footprints by seven Tourism Villages were then used as a reference to build "The Low-Carbon Sustainable Tourism Village Model".

3. Results

3.1. Resources and Visitor Arrival in Tourism Village

Based on this study, six of the Tourism Villages were located at the foot of mountains, with only Kandri situated on the highland near Semarang City. This indicated that Lerep and Candirejo were located on the foothills of Mt. Ungaran and Sumbing, which is not far from the Borobudur Temple. In addition, Karangrejo (the same district as Candirejo) was located on the foothill of Mt. Menoreh, with the Dieng Kulon site situated on the Dieng Plateau between Mt. Sindoro and Sumbing. Meanwhile, Pentingsari was found on the foothill of Mt. Merapi. All these villages had beautiful green landscapes and cool weather, as well as peaceful recreational areas. These seven Tourism Villages also have several venues and products as tourist attractions, as presented by Table 3.

Table 3. Venues and attractions of the seven Tourism Villages in Indonesia considered in this study.

No.	Tourism Village	Venues	Tourism Products
1.	Kandri	(1) Natural venues: Kandri Lake, Gede Lake, Jamu Lake, Kreo Cave, Monkeys population at Kreo Cave; Jatibarang Dam; (2) Culinary venues: Centre of Chips and Cassava Production; Beverages product; Cassava product home industries (Omah Pohung); (3) Omah Alas Art and Culture Studio; (4) Tourist Information Centre; (5) Home Stays	Packages: "Paket Nyawah (Planted Paddy Package)", "Paket Petik Jambu" (Picking Guava Package)
2.	Lerep	(1) Natural venues: Curug Indrakila Waterfall; Embung Sebligo Waterboom; Watu Gunung Natural Swimming Pool; (2) Home Stays	Packages: Education-Tourism Packages (A-F Packages), Eco-Edu Tour Package
3.	Candirejo	(1) Natural sites: Watu Kendil, Tempuran, Tuk Banyu Asin (Ancient Lake); (2) Shops: Food product, stone handycraft, and miscellanous handycraft shops; (3) Home Stays	Packages: One Day Field Trip, Half-Day Field Trip, Live In, Rafting, Dokar (horse cart) Village Tour, Cycling Tour, Live-In, Walking-Around Village, Village Experience, Cooking Lesson, Traditional Dance

Table 3. *Cont.*

No.	Tourism Village	Venues	Tourism Products
4.	Karangrejo	(1) Natural venues: Punthu Setumbuk (Dove Hill), Barede Hill, Chicken Churh, Karangrejo Fruit Park; (2) Shops: Batik Shop, Culinary Shops; (3) Home Stays; (4) Events: Sedekah Bumi (Traditional Thanksgiving Ceremony), Desa Budaya (Cultural Village)	Packages: Traditional Farming Education, Jeep Sumringah Tour, VW (Volks Wagen) Sumilir Packages, Onthel Manunggal (Biking Tour)
5.	Dieng Kulon	(1) Natural venues: Sikidang Crater, Arjuna Temple, and Kaliasa Dieng Museum; (2) Culinary shops; (3) Home Stays; (4) Events: Dieng Kulon Festival, Jazz Above the Sky	Non-Package
6.	Samiran	(1) Natural venues: Gua Raja (King Cave), Petilasan Kebo Kanigara (Kebo Kanigara) Heritage Site, Mt. Merapi, Mt. Merbabu, Argadewi Agro-Tourism; (2) Shops: Diary products shops, Vegetables Shops; (3) Home Stays	Packages: custom-made packages, One-Day Package, Two-Days Package, Wisata Petik Sayur (Picking Vegetables Package), learning gamelan (traditional Javanese music instruments) packages, milking cows learning package, Reog Dance learning package.
7.	Pentingsari	(1) Natural venue: Outbond Area; (2) Restaurants: Warunge Simbok (Mom's Cafetaria); (3) Shops: Batik Shop, Culinary Shops; (4) Home Stays	Packages: Family Package, Live-In; Jeep Lava Tour Merapi

Among the seven Tourism Villages, Pentingsari and Lerep had the smallest (103 km^2) and largest (682 km^2) areas with the biggest population (9000 persons), respectively, as shown by Table 4. The monthly visitor arrivals were observed before and during the COVID-19 pandemic (2019–2020 and 2020–2021), indicating a drastic decline in all Tourism Villages between 2020–2021 (Table 5). Moreover, four Tourism Villages (Lerep, Candirejo, Karangrejo, and Pentingsari) had zero visitors until December 2021, with Dieng Kulon still having a significant number of tourists during the pandemic (45,000 visitors) to present.

Table 4. Area and population of the seven Tourism Villages in Indonesia considered in this study.

No.	Tourism Village	Area (km^2)	Population (Person)	Population Density (Person/km^2)
1.	Kandri	319.64	3797	11.88
2.	Lerep	682	9000	13.20
3.	Candirejo	300.63	4700	15.63
4.	Karangrejo	174	3016	17.33
5.	Dieng Kulon	210	5300	25.24
6	Samiran	631.11	3715	5.89
7	Pentingsari	103	390	3.79

Table 5. Visitor arrivals in the seven Tourism Villages in Indonesia considered in this study before and during the pandemic.

No.	Tourism Village	Population (Person)	Visitor's Arrival per Month		The Ratio of Visitor to Population	
			Before Pandemic (Person)	During Pandemic (Person)	Before Pandemic (%)	During Pandemic (%)
1.	Kandri	3797	1000	100	26.34	2.63
2.	Lerep	9000	4942	0	54.91	0
3.	Candirejo	4700	750	0	15.96	0
4.	Karangrejo	3016	4000	0	132.63	0
5.	Dieng Kulon	5300	61,500	45,000	1160.38	849.06
6.	Samiran	3715	1030	285	27.73	7.67
7.	Pentingsari	390	2083	0	534.10	0

3.2. Solid Waste Carbon Footprint

According to the field survey, several types of solid waste were found to exist in all Tourism Villages, i.e., food, paper, plastic, and organic pollutants. Since the exact volume of these wastes were unable to be obtained through field survey, significant assumptions were stated based on the number of visitors [28], as shown in Table 5. This indicated that the solid waste volume of seven Tourism Villages was individually calculated daily, with four pollutant categories (food, paper, plastic, and organic) being observed. In addition, the solid waste volume produced by these villages is shown in Figure 3.
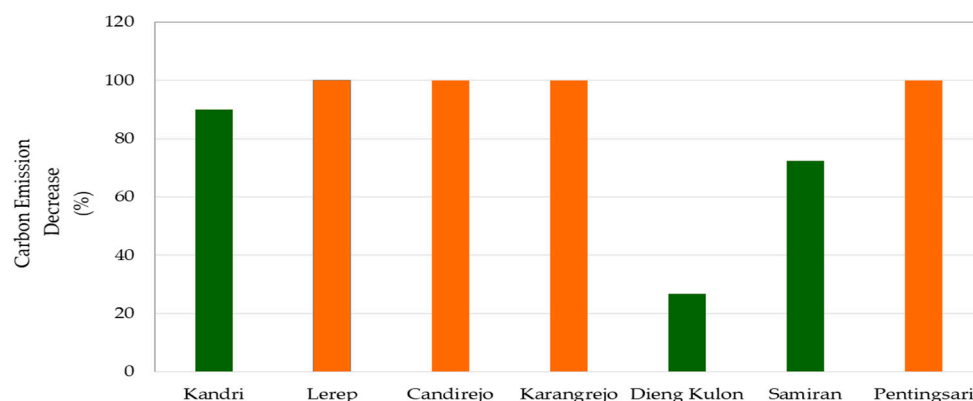

Figure 3. Solid waste CO_2 emission decrease of the seven Tourism Villages in Indonesia considered in this study.

Based on Tables 6 and 7 the solid wastes produced by the tourists before and during the COVID-19 pandemic were described, respectively. According to Table 6, Dieng Kulon produced the biggest solid waste volumes of 913,644 and 668,520 kg/month before and during the pandemic, respectively. The results also showed that the largest organic solid waste volume was found in Dieng Kulon at 609,772.50 and 446,175 kg/month, before and during the COVID-19 pandemic, respectively. Furthermore, the Candirejo and Kandri had the smallest solid waste volumes of 11,142 and 1485.60 kg/month before and during this pandemic, respectively. Based on seven Tourism Villages before the pandemic, Candirejo was found to have the smallest volume of food waste at 522 kg/month. Meanwhile, zero visitors were recorded for Candirejo, Lerep, Karangrejo, and Pentingsari during the pandemic. The results also showed that Lerep and Pentingsari had large organic solid waste volumes of 48,999.93 and 20,652.95 kg/month before the pandemic, from a total of 73,418.35 and 30,945.05 kg/month, respectively. Paper and plastic wastes were found in large volumes at Lerep (11,164 and 9815 kg/month) and Karangrejo (9036 and 7944 kg/month) before the COVID-19 pandemic. This indicates that the organic solid waste volume was quite high in most Tourism Villages before the COVID-19 pandemic.

Table 6. The solid waste volume produced by the visitors of the seven Tourism Villages in Indonesia considered in this study before the COVID-19 pandemic.

No.	Tourism Village	Visitor before Pandemic (Person/Month)	Solid Waste Volume per Category before Pandemic				Total Solid Waste Volume before Pandemic
			Food (kg/Month)	Paper (kg/Month)	Plastic (kg/Month)	Organic (kg/Month)	
1.	Kandri	1000	696.00	2259.00	1986.00	9915.00	14,856.00
2.	Lerep	4942	3439.63	11,163.98	9814.81	48,999.93	73,418.35
3.	Candirejo	750	522.00	1694.25	1489.50	7436.25	11,142.00
4.	Karangrejo	4000	2784.00	9036.00	7944.00	39,660.00	59,424.00
5.	Dieng Kulon	61,500	42,804.00	138,928.50	122,139.00	609,772.50	913,644.00
6.	Samiran	1030	716.88	2326.77	2045.58	10,212.45	15,301.68
7.	Pentingsari	2083	1449.77	4705.50	4136.84	20,652.95	30,945.05

Table 7. The solid waste volume produced by the visitors of the seven Tourism Villages in Indonesia considered in this study during the COVID-19 pandemic.

| No. | Tourism Village | Visitor during Pandemic (Person/Month) | Waste Volume per Category during Pandemic | | | | Total Waste Volume during Pandemic |
			Food (kg/Month)	Paper (kg/Month)	Plastic (kg/Month)	Organic (kg/Month)	
1.	Kandri	100	69.60	225.90	198.60	991.50	1485.60
2.	Lerep	0	0	0	0	0	0
3.	Candirejo	0	0	0	0	0	0
4.	Karangrejo	0	0	0	0	0	0
5.	Dieng Kulon	45,000	31,320.00	101,655.00	89,370.00	446,175.00	668,520.00
6.	Samiran	285	198.36	643.82	566.01	2825.78	4233.96
7.	Pentingsari	0	0	0	0	0	0

Based on Equation (1), the CO_2 emission of solid waste for all Tourism Villages was calculated (Table 8), indicating that Dieng Kulon had the largest monthly solid waste CO_2 emission before and after the COVID-19 pandemic (437,766.10 kg CO_2/kg and 320,316.66 kg CO_2/kg). In addition, Lerep, Karangrejo, and Pentingsari only had high solid waste CO_2 emissions (35,177 kg CO_2/kg, 28,472.59 kg CO_2/kg, and 14,827.10 kg CO_2/kg) before the pandemic. This was due to the zero values of solid waste CO_2 emission during the COVID-19 pandemic. Meanwhile, only Kandri had the smallest solid waste CO_2 emission before and during the COVID-19 pandemic (7118.15 kg CO_2/kg and 711.81 kg CO_2/kg).

Table 8. CO_2 solid waste emission of the seven Tourism Villages in Indonesia considered in this study before and during COVID-19 pandemic.

| No. | Tourism Village | Emission Factor-Inorganic Waste | Emission Factor-Organic Waste | Solid Waste Carbon Emission Produced by Visitor | |
| | | | | Before Pandemic | During Pandemic |
				(kg CO_2/kg)	(kg CO_2/kg)
1.	Kandri	0.668	0.450	7118.15	711.81
2.	Lerep	0.668	0.450	35,177.89	0.00
3.	Candirejo	0.668	0.450	5338.61	0.00
4.	Karangrejo	0.668	0.450	28,472.59	0.00
5.	Dieng Kulon	0.668	0.450	437,766.10	320,316.66
6.	Samiran	0.668	0.450	7331.69	2028.67
7.	Pentingsari	0.668	0.450	14,827.10	0.00

3.3. Building's Carbon Footprint

According to the field survey, the building types found in the seven Tourism Villages were the office, hall, homestay, public toilet, mosque, and shop (Table 9). The results showed that the homestays were the most numerous building types found in all the villages, with most existing in Dieng Kulon (265 buildings), accompanied by Kandri and Candirejo (90 and 80 buildings). Another building type also existing in large numbers was the shop, with Table 9 showing that Dieng Kulon, Lerep, and Samiran had 60, 20, and 15 shops, respectively.

Based on this study, the number and volume of buildings existing in the seven Tourism Villages are shown in Table 10. This indicates that Pentingsari and Lerep, Karangejo and Kandri, as well as Dieng Kulon and Kandri, had the lowest and highest building areas (103 and 682 ha), numbers (91 and 340 buildings), and average volumes (210 and 400 m^3), respectively. According to Table 10, Pentingsari also had the highest building area ratio of 223.30%, accompanied by Karangrejo and Kandri at 155.17% and 125.14%, respectively.

Table 9. The types of buildings in the seven Tourism Villages in Indonesia considered in this study.

| No. | Tourism Village | Type of Building | | | | | | Total Number of Buildings |
		Office	Hall	Home Stay	Public Toilet	Mosque	Shop	
1.	Kandri	1	4	90	3	4	3	105
2.	Lerep	1	3	50	4	13	20	91
3.	Candirejo	1	3	80	8	15	5	112
4.	Karangrejo	10	3	50	6	6	7	82
5.	Dieng Kulon	1	3	265	0	11	60	340
6.	Samiran	2	2	45	6	3	15	73
7.	Pentingsari	1	6	50	40	2	6	105

Table 10. The ratio of building number to the area of the seven Tourism Villages in Indonesia considered in this study.

No.	Tourism Village	Area (ha)	Number of Buildings (pcs)	Average Building's Area (m^2)	Total Building's Area (m^3)	Ratio of Building's Number to Area (Building/m^2)
1.	Kandri	320	105	133.33	14,000.00	0.33
2.	Lerep	682	91	100.00	9100.00	0.13
3.	Candirejo	301	112	83.33	9333.33	0.37
4.	Karangrejo	174	82	90.00	7380.00	0.47
5.	Dieng Kulon	210	340	70.00	23,800.00	1.62
6.	Samiran	631	73	76.67	5596.67	0.12
7.	Pentingsari	103	105	76.67	8050.00	1.02

Using Equation (2), all the building types in the seven Tourism Villages were calculated for building's CO_2 emission. According to Table 11, the homestays had the highest CO_2 emission of 80–90% in all locations. Also, the highest and lowest total building's CO_2 emissions were observed at Dieng Kulon (159,460 kg CO_2/m^2) and Samiran (37,499.30 kg CO_2/m^2), respectively. Kandri also had approximately 86% of the highest home stay's CO_2 emission at 80,398 kg CO_2/m^2. In addition, Lerep, Candirejo, and Pentingsari had about 25–30% home stay's CO_2 emission compared to total building's CO_2 emissions respectively.

Table 11. The building's CO_2 emission of the seven Tourism Villages in Indonesia considered in this study.

| No. | Tourism Village | Building's CO_2 Emission (kg CO_2/m^2) | | | | | | Total Building's CO_2 Emission (kg CO_2/m^2) |
		Office	Hall	Home Stay	Public Toilet	Mosque	Shops	
1.	Kandri	893	3573	80,398	2680	3573	2680	93,797.66
2.	Lerep	670	2010	33,500	2680	8710	13,400	60,970.00
3.	Candirejo	558	1675	44,665	4466	8375	2792	62,530.83
4.	Karangrejo	6030	1809	30,150	3618	3618	4221	49,446.00
5.	Dieng Kulon	469	1407	124,285	0	5159	28,140	159,460.00
6.	Samiran	1027	1027	23,116	3082	1541	7705	37,499.30
7.	Pentingsari	514	3082	25,684	20,548	1027	3082	53,937.35

4. Discussion

4.1. Carbon Footprint Analysis

Based on this study, the seven Tourism Villages had beautiful scenes that were very attractive to both domestic and foreign visitors, with all the locations having low population densities (Tables 2 and 3). However, the arrival of visitors before the pandemic was very high, with the minimum and maximum values observed at Candirejo and Dieng Kulon (750 and 61,500 visitors/month), respectively. The high values of Dieng Kulon were due

to the famous scenes of the Dieng Plateau and Arjuna Temple. Despite the decline during the COVID-19 pandemic, the solid waste and CO_2 emissions produced in this area were still high (Figure 4). Based on Figure 3, the four villages (Lerep, Candirejo, Karangrejo, and Pentingsari) with zero visitors during the pandemic were represented by orange bars. From these four villages, 3 locations (Lerep, Karangrejo, and Pentingsari) still had high CO_2 emissions (35,177.89 kg CO_2, 28,472.59 kg CO_2, and 14,827.10 kg CO_2), as illustrated in Figure 4. However, there was no significant reduction guarantee towards future visits. In this study, organic waste had the highest volume before and during the COVID-19 pandemic, indicating a large CO_2 emission contribution (Figure 3). By implementing waste recycling as a proper management technique, the concerns of organic pollutants in these Tourism Villages should not be a problem.
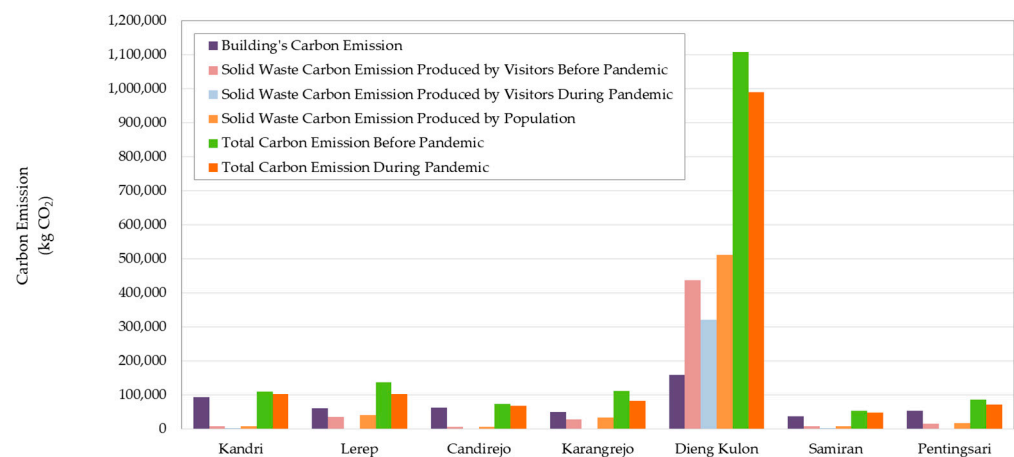

Figure 4. CO_2 emissions from several sources produced by the seven Tourism Villages in Indonesia considered in this study.

It is obvious that a large number of visitors and population will produce a large volume of waste, as discussed in the previous sub-section. However, a comparison among the tourism areas should provide a better understanding of the waste produced by the activities of a certain population. This led to the comparisons of the solid waste produced by the seven Tourism Villages with that produced by the Nusa Penida Islands. This tourism location had three subareas, namely Nusa Peninda, Lembongan, and Ceningan Islands, respectively. The waste volume data of the Nusa Penida Islands was in line with a previous study [20], and also current study which is explained by Table 9, where the Emission Factor (0.559) used for calculation was the average value of rural household inorganic (0.668) and organic (0.45) pollutants. Table 12 indicates that all seven Tourism Villages in this study produced a larger waste volume compared to those in Nusa Penida Islands. Therefore, the CO_2 emission produced by the solid waste in these villages was between 200–22,000% larger than the waste CO_2 emission in the Nusa Penida Islands. Despite Nusa Penida Island having the highest population and density (190.04 person/km^2) among all the locations in Table 12, it still only produced a carbon emission of 2299 kg CO_2. Besides that, Lerep had the largest population (9000 persons) among the seven Tourism Villages, although it was not the most crowded location, as the density was only observed at 13.20 person/km^2. Meanwhile, Dieng Kulon was the most crowded at 25.24 person/km^2, thereby becoming the highest contributor of carbon emission at 510,727 kg CO_2/kg.

Based on this study, it is interesting to analyze the carbon emission produced by the population of both Dieng Kulon and Nusa Penida Island (Table 12). Although the population density of Dieng Kulon was only 13.28% that of Nusa Penida Island, the waste CO_2 emission was still 22,215.19%. This shows that when the wastes produced by the visitors and population of Dieng Kulon were added together before the pandemic (Tables 5 and 8), the waste CO_2 emission was 948,493.10 kg CO_2/kg. According to [20], the visitors of Nusa Penida Islands (all 3 islands included) were 391,071 daily or 11,732,130 monthly,

subsequently producing waste of 5208.3 kg/month. After calculations, the total waste CO_2 emission was found at 34,157,389,047.56 kg CO_2/kg or 34,157,389.05 t CO_2/kg. This indicated that a large number of visitors generated high carbon waste emissions, which was in line with the data of Dieng Kulon and Nusa Penida Island. However, further analysis showed that each visitor in Nusa Penida Islands and Dieng Kulon only produced wastes of 0.00044/172.39 kg/day or 0.01332/5.75 kg/month, respectively. This indicated that each person in Dieng Kulon contributed higher waste CO_2 emission (96.36 kg CO_2/kg per day or 3.21 kg CO_2/kg per month) than those in the Nusa Penida Islands (0.00025 kg CO_2/kg per day or 0.00745 kg CO_2/kg per month).

Table 12. The waste volume and CO_2 emission produced by the population of the seven Tourism Villages in Indonesia considered in this study and the Nusa Penida Islands.

Location	Area (km^2)	Population (Person)	Population Density (Person/km^2)	Solid Waste Composition	Total Volume of Solid Waste	Average Emission Factor	CO_2 Emission (kg CO_2/kg)
Kandri	319.64	3797	11.88		14,856	0.559	8304.50
Lerep	682	9000	13.20		73,418	0.559	41,040.66
Candirejo	300.63	4700	15.63	Food, paper, plastic, organic waste	11,142	0.559	6228.38
Karangrejo	174	3016	17.33		59,424	0.559	33,218.02
Dieng Kulon	210	5300	25.24		913,644	0.559	510,727.00
Samiran	631.11	3715	5.89		15,302	0.559	8553.82
Pentingsari	103	390	3.79		30,945	0.559	17,298.26
Nusa Penida *	202.17	38,421	190.04	Food, wood and garden waste, paper, textile, rubber and leather, plastic, glass, metal, hazardous waste, etc.	4112.70	0.559	2299.00
Nusa Lembongan *	800	5163	6.45		764.40	0.559	427.30
Nusa Ceningan *	300.9	1992	6.62		331.20	0.559	185.14

* Data of population and daily waste volume referred to [20].

Based on Tables 10 and 11, Dieng Kulon and Samiran had the highest and lowest ratios of area numbers (1.62 and 0.12) and CO_2 emissions (159,460 and 377,499.3 kg CO_2/m^2), respectively. This indicates that the large values of building's CO_2 emission were due to the high number of existing buildings in the area. According to this study, Dieng Kulon had the largest number of buildings (340 buildings), with most found to be homestays (265 homestays). Therefore, the CO_2 emission produced by the seven Tourism Villages was a 'red flag' of environmental quality degradation, which should immediately be mitigated. In wider aspects, Dieng Kulon was found as the 'top rank' contributor of carbon emissions, as shown in Figure 4. This was because the large population and a great number of visitors had made this village a 'giant' of CO_2 emission, compared to Nusa Penida Islands (Table 12). In addition, Figure 4 showed that Kandri and Lerep had slightly larger carbon emissions compared to Candirejo, Karangrejo, Samiran, and Pentingsari. This indicates that most of the Tourism Villages (Dieng Kulon Village excluded) had larger carbon waste from buildings than the solid pollutant emission. Therefore, the high solid-waste CO_2 emission in Dieng Kulon was contributed by visitors and the population.

Based on Table 13, Dieng Kulon had the highest CO_2 emissions from all sources (solid waste produced by visitors, population, and buildings). The results also showed that Candirejo had the lowest emission produced by the visitors and population, before the COVID-19 pandemic. However, Kandri and Samiran had the lowest CO_2 emissions produced by visitors and buildings, respectively.

Table 13. The maximum and minimum CO_2 emissions from all sources in the current study.

No.	Types of Carbon Emission	Maximum (Tourism Village, Amount)	Minimum (Tourism Village, Amount)
1.	Solid waste CO_2 emission produced by visitors before the pandemic	Dieng Kulon 437,766.10 kg CO_2/kg	Candirejo 5338.61 kg CO_2/kg
2.	Solid waste CO_2 emission produced by visitors during the pandemic	Dieng Kulon 320,316.66 kg CO_2/kg	Kandri 711.81 kg CO_2/kg
3.	Solid waste CO_2 emission produced by the population	Dieng Kulon 510,727.00 kg CO_2/kg	Candirejo 6228.38 kg CO_2/kg
4.	Building's CO_2 emission	Dieng Kulon 159,460.00 kg CO_2/m^2	Samiran 37,499.30 kg CO_2/m^2

This indicates that the high number of CO_2 emissions was due to the large volume of solid waste produced by the visitors and the population. In addition, the high pollutant volume implied the bad habits of people (residents of the Tourism Villages and visitors) in producing solid wastes, and also the inappropriate trash management (3R—Reduce, Reuse, and Recycle).

4.2. Comprehensive Model

A low-carbon approach should be implemented in these seven Tourism Villages, including decreased energy consumption, pollution, and CO_2 emissions [22]. This indicates that a change of paradigm is needed, due to individual awareness, attitudes, capacity to change, as well as social alterations such as the cultures and environments in Tourism Villages. Furthermore, a social education of low-carbon habits was necessary for achieving better environmental qualities (cleaner, healthier, and sustainable), indicating that the community should lead health management, create societal strength, and develop a sustainable Tourism Village [7]. The stakeholders (government, tourism village's community, population, tourists or visitors) of Tourism Village development should also be involved in implementing low-carbon sustainability [13].

Based on the problems of CO_2 emissions produced by Tourism Villages, this study proposed a comprehensive model called the "Low-Carbon Sustainable Tourism Village Model" (Figure 5). The model essentials may be explained as follows. The model is described by a chart with several colors of rectangles to distinguish their meanings, which are also stated in the figure, and connected by arrows that described flow and causality. The Tourism Village is the center of this model, which is represented by a green rectangle because of its 'green characteristic'. However, the Tourism Village has contributed large CO_2 emissions (which are represented by a red rectangle that marked it as very important aspect) from its elements (which are marked by orange rectangles) such as infrastructures, population, and visitors. The CO_2 emissions produced by the Tourism Village's elements has contributed to climate change (that is marked by a blue rectangle). It is explained by the model that the buildings are infrastructure elements of the Tourism Village that produce a significant amount of CO_2 emissions that may come from venues, homestays, heritage sites, shops, public infrastructures, etc. Due to the large contribution of carbon emissions from the Tourism Village, it is necessary to conduct carbon footprint reduction programs, i.e., waste management, evaluation of building operation and maintenance, energy efficiency, etc. These actions should be accompanied by the social education of low-carbon habits, such as promoting and building awareness, attitudes, and planning capacity, as well as implementing sustainable tourism programs. This educational method is expected to develop an essential low-carbon habit, which should involve internal stakeholders Tourism Village's community) and external stakeholders (government) due to

policy, regulation, and law enforcement). Therefore, the low-carbon Tourism Village is a good way to achieve sustainability.
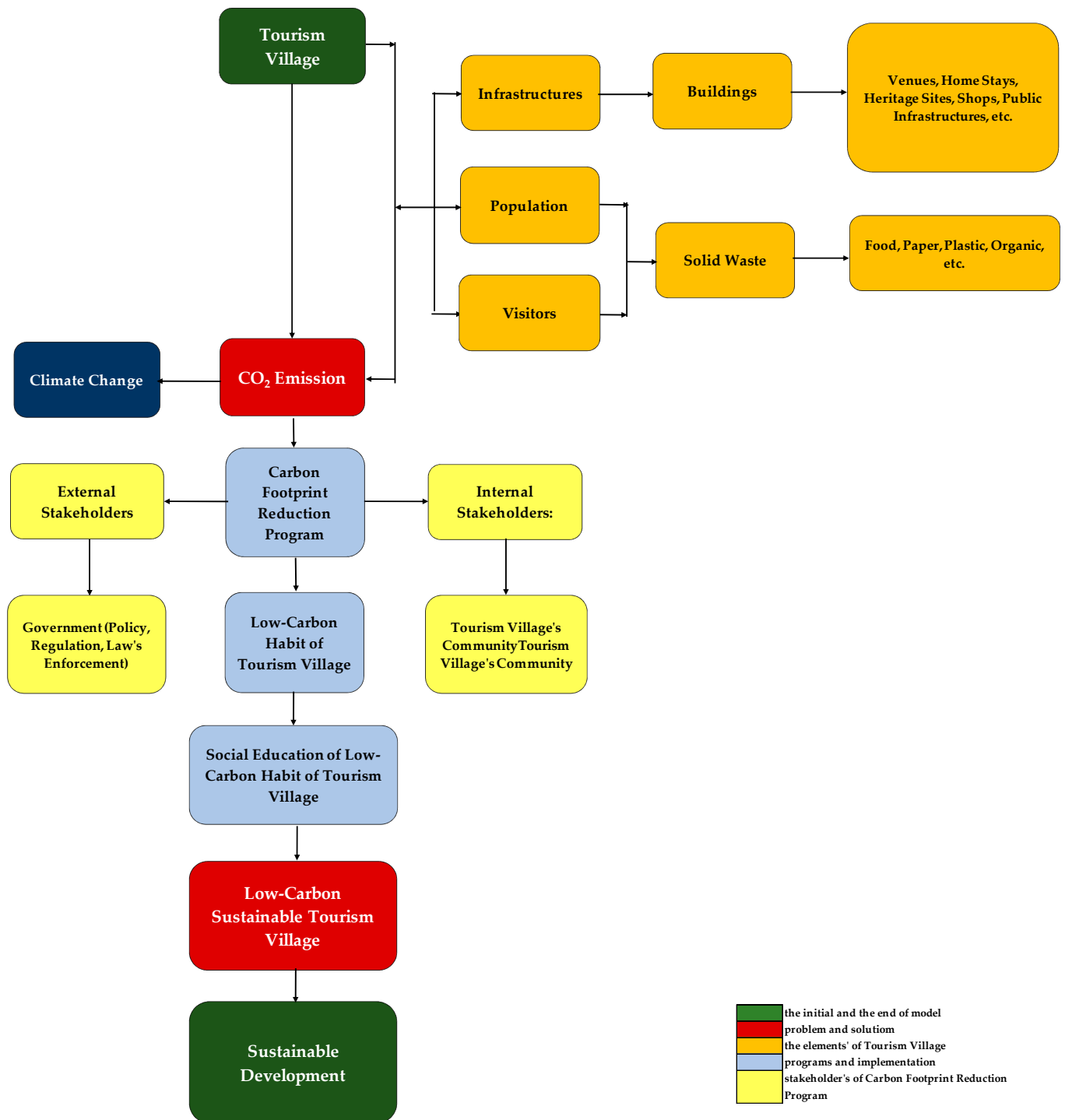

Figure 5. The Low-Carbon Sustainable Tourism Village Schematic Model.

5. Conclusions

This study focused on the high contribution of tourism activities to the carbon footprint. There is no doubt that Tourism Villages have contributed large CO_2 emissions by the tourist attractions which were the main business of the seven Tourism Villages in Indonesia considered in this study, as well as in the heritage sites of Yogyakarta Special Region in Indonesia and also the Wulingyuan Scenic/Historic Interest Area (WSHIA) and

Guizhou ethnic locations in China [11–13]. For the new concept of low-carbon tourism to be implemented to increase the wealth of the tourism industry's actors [7–10], several actions in low-carbon approaches are a necessity. Lessons learned about proper waste management from tourism areas of Madeira Island, Portugal [18] and Coachella Valley, California, USA [19] will be valuable to the Tourism Villages, which have large numbers of visitors and populations, as in Dieng Kulon Tourism Village. It is also important that buildings' life cycles related to energy consumption contain several stages, in addition to their operation and maintenance [25], which in Tourism Villages should be handled with high efficiency to reduce carbon emissions.

Hence, as a "carbon emission contributor" and "victim of the COVID-19 pandemic", the sustainability of Tourism Villages was found to be a key in the development of income, as well as obtaining a cleaner and healthier environment. This should subsequently become the vanguard to lead the economic recovery of rural communities after the pandemic, to reduce carbon emission and achieve sustainable development goals. In addition, the "The Low-Carbon Sustainable Tourism Village Model" was proposed by this study to answer the challenge of sustainability.

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