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Decarbonisation Pathways for Iskandar Malaysia: Insights from the Extended Snapshot Model

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Iskandar Malaysia, an urban region consisting of three (3) districts and falling under the jurisdiction of five (5) local authority bodies, is at the forefront of Malaysia's effort to combat climate change. In line with Malaysia's commitment under the Paris Agreement to reduce greenhouse gas (GHG) emission intensity of GDP by 45 % by 2030, compared to 2005 levels, and the goal set forth in the Twelfth Malaysia Plan to achieve carbon neutrality by 2050, Iskandar Malaysia must intensify its effort to maximize emission reductions across all sectors. This paper aims to project GHG emissions for the five (5) local authorities up to 2050, accounting for existing initiatives, while also investigating alternative decarbonization pathways through the Extended Snapshot (ExSS) model. Two scenarios were developed: Scenario 1 (S1) reflects Business as Usual (BAU) and Scenario 2 (S2) illustrates Counter Measure (CM). The modelling results reveal a significant potential for reducing GHG emissions by 9,870 kt CO_2-eq by 2030 (equivalent to 71 % reduction in emission intensity of GDP compared to the 2010 levels). Among the various emission sectors, transportation, industry, and commercial activities emerge as key areas with high mitigation potential. Each of the five (5) local authorities in Iskandar Malaysia presents different sets of sectoral potentials and challenges regarding their contributions to the region's overall GHG emission reduction. Effective cross-authority coordination is essential to address diverse challenges and maximize emission reduction efforts across the region.

1. Introduction

Climate change represents a critical global challenge that necessitates urgent efforts to reduce greenhouse gas (GHG) emissions worldwide. Although Malaysia's share of global GHG emissions was 0.67 % (amounting to 302 $MtCO_2e$) in 2020, this figure reflects a significant upward trend over the past decades, with a compound annual growth rate (CAGR) of 4.6 % from 1990 to 2020 (Emission Index, 2024). In response to this escalating trend and as part of its commitment to the Paris Agreement, Malaysia has pledged to reduce the GHG emissions intensity of GDP by 45 % by 2030 compared to 2005 levels. The Twelfth Malaysia Plan further sets a target for the nation to achieve carbon neutrality by 2050. Since 2012, Iskandar Malaysia has been a pioneer in low-carbon development, implementing a series of state-level climate change responses and low-carbon initiatives. With a vision to achieve carbon neutrality as early as 2050, Iskandar Malaysia has become a focal point for innovative approaches to decarbonisation. Central to this endeavour is the need for scientific analysis to understand current emissions levels, forecast future trajectories, and delineate effective pathways for emission reduction. This paper aims to estimate GHG emissions by end-use sector for five (5) local authorities in Iskandar Malaysia, using 2010 as the base year for analysis. By projecting emissions under both Business-as-Usual (BAU) and Counter Measure (CM) scenarios for 2030 and 2050, utilizing the Extended Snapshot (ExSS) model, this study endeavours to provide valuable insights into potential pathways for decarbonization in Iskandar Malaysia. The findings presented in this paper are intended to serve as a framework for other regions in Malaysia and similar urban areas in Asian countries, providing a valuable resource for policymakers, stakeholders, and researchers. These insights aim to guide efforts towards a more sustainable and resilient future for Iskandar Malaysia and beyond.

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1.1 Overview of Iskandar Malaysia

Iskandar Malaysia, established in 2006, is a dynamic and rapidly developing economic region situated in the southern part of Peninsular Malaysia, adjacent to Singapore. It is recognized as the country's second major metropolitan area after Greater Kuala Lumpur (Johar and Adawiyah, 2014). The planning boundary in this study covers a total area of 273,700 hectares, encompassing the districts of Johor Bahru, Kulai, and Pontian. The urban regions within Iskandar Malaysia are governed by five (5) local authority bodies: Johor Bahru City Council (MBJB), Iskandar Puteri City Council (MBIP), Pasir Gudang City Council (MBPG), Kulai Municipal Council (MPKu) and Pontian Municipal Council (MPPn). Figure 1 presents a detailed map illustrating the geographic boundaries and jurisdictional areas of these five (5) local authorities within Iskandar Malaysia.

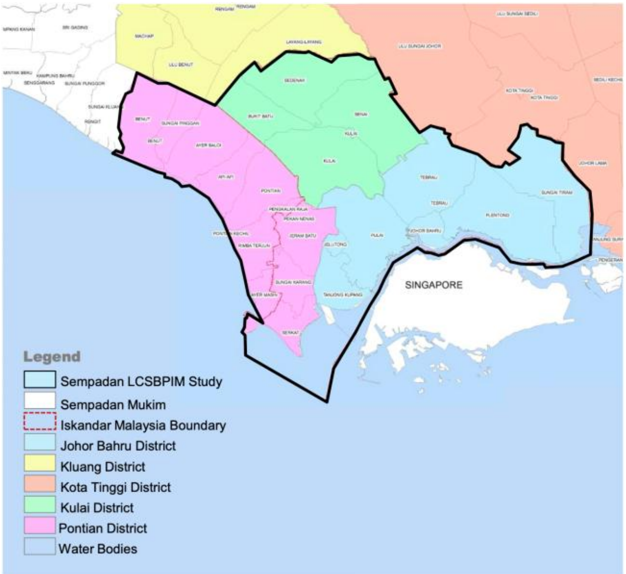

Figure 1: Geographic boundaries and jurisdictional areas of local authorities within Iskandar Malaysia (Low *Carbon Asia Research Center, 2022).*

2. Research Method

The Asia–Pacific Integrated Modeling System (AIM) is an Extended Snapshot Tool (ExSS) was developed by Kyoto University and Japan's National Institute for Environmental Studies (NIES) to create low-carbon scenarios (Abdul-Azeez, 2016). This modelling tool, which incorporates predetermined socioeconomic, industrial, and demographic scenarios, is intended to assess future energy consumption, power generation, technology diffusion, transportation, industrial outputs, residential and commercial activities, waste generation, and GHG emissions for a specific future or target year. It is divided into four (4) modules: 1) driving variables such as population and GDP growth, 2) energy service demand, 3) primary energy supply analysis, and 4) GHG emissions calculated using the Kaya Identity in Eq(1). In this formula, *F* represents GHG emissions from human activity, *P* represents population, *G* represents GDP, and *E* represents energy consumption (Penn State Department of Meteorology, 2015).

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \tag{1}$$

In this study, the ExSS tool, along with a solid waste model and carbon sink model, was adopted to quantify emissions in Iskandar Malaysia. To estimate the total GHG emissions for Iskandar Malaysia, three (3) primary sources of GHG were considered: 1) energy, 2) waste, and 3) carbon sinks. The ExSS tool was utilized to estimate GHG emissions from the energy sector, which included both energy demand and supply. Data required for energy demand encompass factors such as population, number of households, GDP, transportation data, as well as residential, commercial, and industrial data. For energy supply, data on electricity generation and secondary energy sources are needed. For quantifying GHG emissions from the waste sector, the necessary data include waste generation volumes, waste composition, recycling and composting rates, and waste treatment technologies. In terms of carbon sinks, CO_2 equivalents are calculated from forests and urban parks. Using the basic Kaya Identity equation, this study established baseline results based on the driving forces, with the AIM tool having generated GHG emissions for the base year 2010 and projected Business as Usual (BaU) and Counter Measure (CM) scenarios for 2030 and 2050.

3. Result and Discussion

3.1 Iskandar Malaysia GHG Emission Key Driving Force

Figure 2 illustrates the key driving force behind the growth and development of Iskandar Malaysia from 2010 to projections for 2030 and 2050. The data reveals significant growth in affluence, population, and economic activities, which are expected to substantially increase consumption levels of mobility, goods, and services. Consequently, this will lead to higher end-use energy consumption and GHG emissions.

In 2010, the GDP of Iskandar Malaysia was RM 42.66 billion. This figure is projected to rise substantially to RM 154.43 billion by 2030 and further to RM 440.29 billion by 2050. This economic expansion is primarily driven by activities in the tertiary sector, which is set to grow from 54 % in 2010 to 65 % by 2030 and maintain this proportion through 2050. Meanwhile, the secondary sector is expected to decrease from 45 % in 2010 to 34.1 % by 2030 and hold steady thereafter, while the primary sector remains minimal at around 1 %. The population of Iskandar Malaysia is also projected to grow from 1.73 M 2010 to 2.50 M by 2030, reaching 3.07 M by 2050. This demographic growth is mirrored in the increase in GDP per capita, which is forecasted to rise from RM 24.49 thousand in 2010 to RM 61.77 thousand in 2030, and eventually to RM 143.22 thousand by 2050.

A significant shift in transportation modes is anticipated, with the modal share of passenger transport moving from 84 % private and 16 % public in 2010 to 65 % private and 35 % public by 2030, and ultimately to a balanced 50 % each by 2050. This shift is expected to be achieved through the implementation of effective low-carbon society (LCS) mobility policies, which will potentially reduce GHG emissions in the transportation sector.

The commercial floor area in Iskandar Malaysia is expected to expand significantly from 14.42 km² in 2010 to 26.25 km² by 2030, and further to 74.85 km² by 2050. This increase will likely lead to a rise in stationary energy consumption and GHG emissions in the commercial sector. This highlights the necessity for introducing progressive reduction measures towards 2030 and 2050 to mitigate the environmental impact.

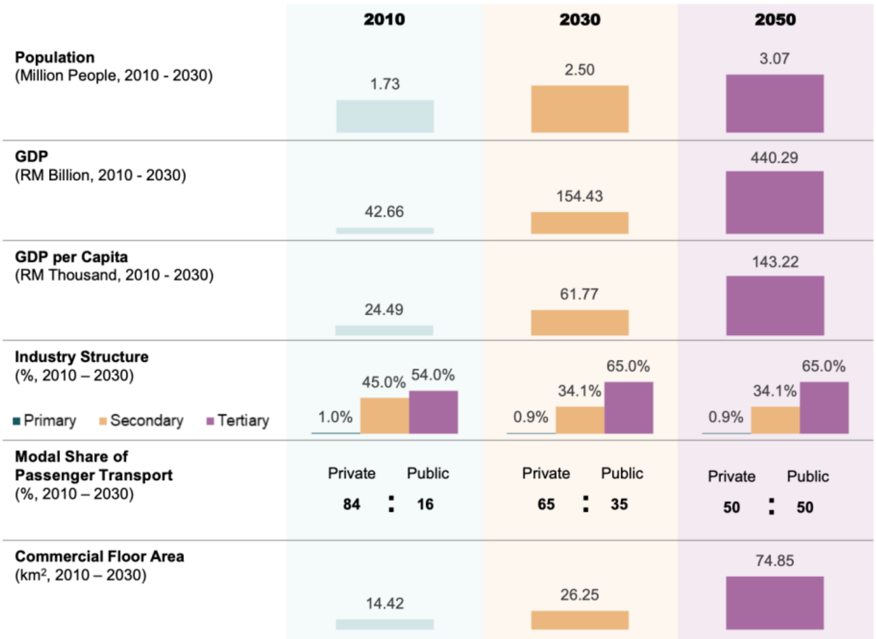

Figure 2: Iskandar Malaysia GHG emission key driving force (Low Carbon Asia Research Center, 2022).

3.2 Iskandar Malaysia GHG Emission Modelling Result

Based on Figure 3, the preliminary GHG emission modelling results for Iskandar Malaysia shows a significant increase in emissions from 12,627 kt CO_2-eq in 2010 to 23,283 kt CO_2-eq by 2030 under a BaU scenario, primarily driven by growth in industry, transport, and commercial sectors. This represents an 84 % increase in total emissions from 2010 levels. In CM scenario, emissions could be reduced to 13,412 kt CO_2-eq by 2030, demonstrating a 42 % reduction from the BaU scenario.

Looking ahead to 2050, total GHG emissions are projected to increase substantially to 54,595 kt CO_2-eq under the BaU scenario, with the industry, transport, and commercial sector contributing significantly to this increase. In contrast, with effective CM strategies by 2050, total GHG emissions could be drastically reduced to 11,737 kt CO_2-eq, supported by a more substantial carbon sink of -8,877 kt CO_2-eq.

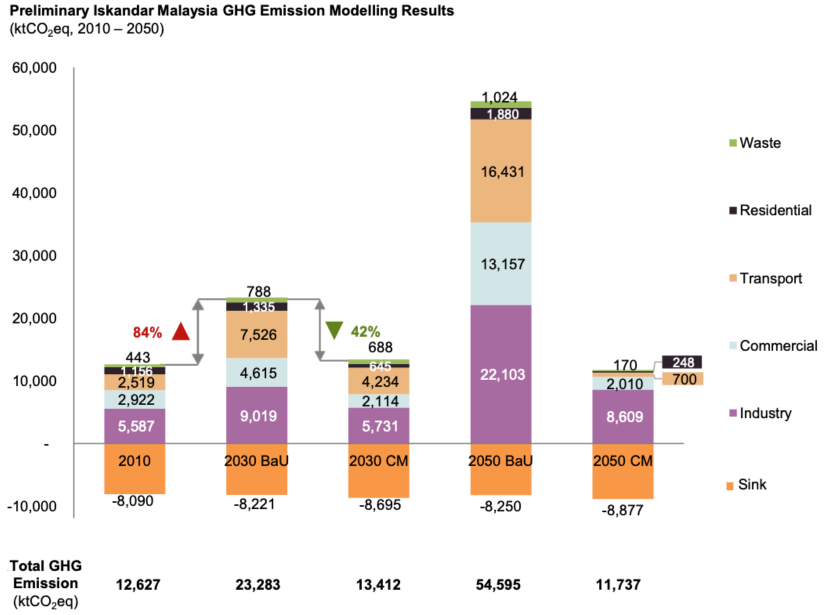

Figure 3: Iskandar Malaysia GHG emission modelling result *(Low Carbon Asia Research Center, 2022).*

3.3 GHG Emission by End-Use Sector by Local Authorities in Iskandar Malaysia

Figure 4 presents the GHG emissions by end-use sector across five (5) local authorities in Iskandar Malaysia for the years 2010 and projected scenarios for 2030 under BaU and CM. The key sectors analyzed include residential, commercial, industry, passenger transport, freight transport, and municipal waste, with an additional category for carbon sink.

In 2010, the highest GHG emissions were recorded in MBJB at 3,523 kt CO_2-eq, followed by MBIP, MBPG, MPKu, and MPPn. The projections for 2030 under BaU scenario show significant increase in emissions, notably in MBJB (6,407 kt CO_2-eq) and MBIP (5,911 kt CO_2-eq), driven primarily by industrial and transport sectors. However, the CM scenarios indicate substantial reductions across all authorities, with MBJB and MBIP showing the most significant decreases to 3,616 kt CO_2-eq and 3,338 kt CO_2-eq. This reduction is largely attributed to enhanced carbon sinks and lower emissions from the transport and industrial sectors.

Notably, the carbon sink contributions (represented as negative values) are crucial in offsetting emissions, especially in the CM scenarios, with MPPn demonstrating the highest offset (-3,197 kt CO_2-eq in 2030 CM). The data underscore the critical role of targeted interventions in transport and industrial sectors and carbon sequestration in mitigating GHG emissions.

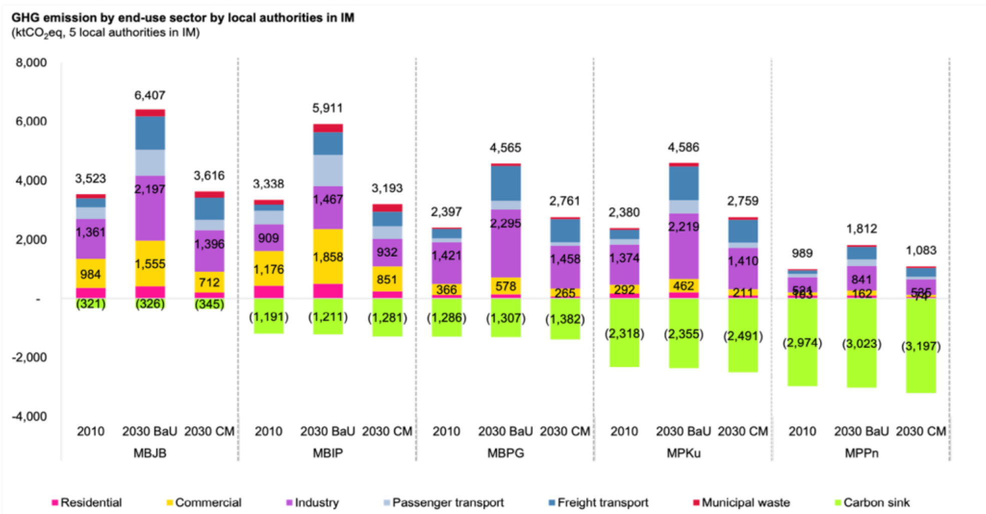

Figure 4: GHG emission by end-use sector by local authorities in Iskandar Malaysia (Low Carbon Asia Research Center, 2022).

3.4 Potential GHG Emission Reduction Contribution by Iskandar Malaysia's Local Authorities

MBJB, contributing 28 % to the total reduction, potentially achieves the biggest GHG emission reduction in Iskandar Malaysia, totaling 2,791 kt CO_2-eq in 2030. The city presents significant mitigation opportunities in the commercial sector (843 kt CO_2-eq), industry (801 kt CO_2-eq) and both passenger (529 kt CO_2-eq) and freight transportation (379 kt CO_2-eq) sectors.

MBIP, also contributing 28 %, is the second-largest potential contributor to GHG emission reduction, with a total potential of 2,718 kt CO_2-eq. This city shows high mitigation potentials in the commercial (1,007 kt CO_2-eq), passenger transportation (635 kt CO_2-eq), industry (535 kt CO_2-eq), and freight transportation (253 kt CO_2-eq) sectors. Other significant contributions come from the residential (kt CO_2-eq) sectors.

For MBPG, which contributes 18 % to the total reduction with a potential of 1,804 kt CO_2-eq, notable mitigation opportunities exist in the industry (836 kt CO_2-eq), commercial (313 kt CO_2-eq), and freight (395 kt CO_2-eq) and passenger (178 kt CO_2-eq) transportation sectors.

MPKu, contributing 19 % to the total reduction with a potential of 1,827 kt CO_2-eq, shows the biggest reduction potentials in the industry (809 kt CO_2-eq), freight transportation (382 kt CO_2-eq), passenger transportation (266 kt CO_2-eq), and commercial (250 kt CO_2-eq) sectors.

MPPn, contributing 7 % and the smallest contributor to GHG emission reduction, with a total of 729 kt CO_2-eq. MPPn is the biggest contributor to the regional carbon sink (-174 kt CO_2-eq). In this area, GHG emission reductions may be achieved primarily in the industry (307 kt CO_2-eq), freight transportation (145 kt CO_2-eq), and passenger transportation (130 kt CO_2-eq) sectors.

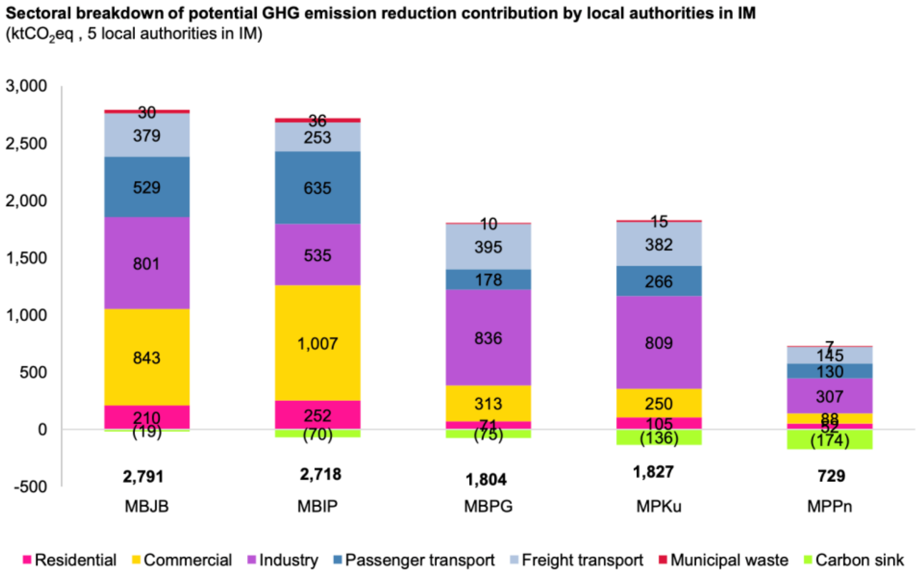

Figure 5: Sectoral breakdown of potential GHG emission reduction contribution by local authorities in Iskandar Malaysia (Low Carbon Asia Research Center, 2022).

3.5 Iskandar Malaysia Carbon Neutrality Pathway

Figures 6 and 7 indicate that Iskandar Malaysia can potentially achieve significant reductions in GHG emissions intensity and absolute emissions by 2030 and 2050. Specifically, Figure 6 shows that the GHG emission intensity of GDP can be reduced by 71 % by 2030 from the 2010 baseline under the CM scenario, equivalent to an absolute reduction of 9,870 kt CO_2-eq (refer to Figure 7). In contrast, Iskandar Malaysia can achieve only a 49 % reduction in emissions intensity under BaU scenario by the same year. By 2050, under the CM scenario, the GHG emission intensity is projected to be reduced by 91 % from the baseline year, equivalent to an absolute reduction of 42,859 kt CO_2-eq, compared to a 58 % reduction in emissions intensity under the BaU scenario.

This significant reduction can be achieved through potential measures such as developing green transportation and mobility options, promoting renewable energy and energy efficiency projects, and advancing green building assessment and recognition. These findings suggest that with robust climate mitigation efforts, Iskandar Malaysia could significantly lower its GHG emissions intensity, achieving a 71 % reduction by 2030 and a 91 % reduction by 2050 compared to the 2010 base year.

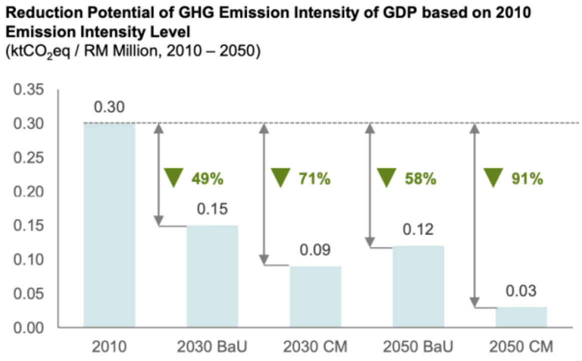

Figure 6: Reduction potential of GHG emission intensity of GDP based on 2010 emission intensity level (Low Carbon Asia Research Center, 2022).

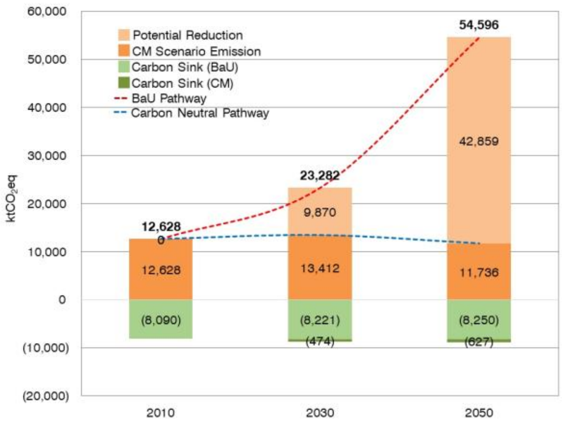

Figure 7: Iskandar Malaysia carbon neutrality pathways (Low Carbon Asia Research Center, 2022).

4. Conclusions

The analysis of GHG emissions in Iskandar Malaysia highlights significant potential for reducing emissions, especially in transportation, industry, and commercial sectors. Under the CM scenario, a 71% reduction in GHG intensity of GDP by 2030 compared to 2010 levels is achievable, leading towards a Low-Carbon Scenario (LCS) and carbon neutrality by 2050. To achieve net zero, the residual emissions of 2,860 kt CO_2-eq (5.24 % of the total emissions in 2050 under the CM scenario) should be mitigated through carbon offset mechanisms. The findings underscore the vital role of city-to-city (C2C) collaboration, particularly between MBJB and MBIP at the city council level, in integrating climate-smart solutions and advancing carbon mitigation efforts that can be shared with other local authorities in Iskandar Malaysia. Future research should include inventory checks to ensure the accuracy of predictions. The methodological approach and decarbonization strategies outlined in this paper can be applied and generalized to other cities aspiring to achieve carbon neutrality by 2050.

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