

Article

Metabolic Aspects of Rural Life and Settlement Coexistence in China

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Abstract: Among realms of settlement coexistences, *desakota* areas or *Township-Village-Enterprises* in China stand out as relatively conservative of material and other resources, including embodied energy. Chencun Village in the Shunde District of Guangdong Province is an agriculturally productive example of such a settlement covering some 131 hectares in area and hosting some 6,000 inhabitants, including villagers and migrant so-called “floating” households. Formerly a center of sericulture, the village now produces flowers and plants, alongside some factory operations making needed hardware in support of agriculture. From a metabolic perspective consisting of what Chencun is made of in material flows of stocks, including material extracted from the Geosphere, Biosphere, and Hydrosphere resulting in building materials, buildings, and land-uses, alongside of collected waste and recycling, the village’s environmental performance is comparatively better than many other forms of settlement coexistence. Measured by stock-flow models represented by Sankey Diagrams, Chencun registers slightly lower than an average of 4.0 MJ/Kg/Yr. or about 106 metric tons of building material per year, below that of more compact and even peripheral modes of settlement. Water use, though very present due to agricultural production takes place in a non-water-stressed part of China and benefits from graywater recycling. Energy use is likewise relatively restrained due to the small amount of transportation and the largely compact and stay-at-home pattern of *desakota* life. Further, such *desakota* forms of settlement should be preserved as more environmentally suitable than denser and more profligate forms of settlement in emerging Metropolitan Regions of China like the Greater Bay Area.

Keywords: metabolism; rural life; *desakota* areas; stock flows; Sankey diagrams; environmental performance



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1. Introduction

Since the onset of the Anthropocene era, global urbanization has placed increasing pressure on natural resources and ecosystems (Doussard et al., 2024; Gao & O’Neill, 2020; Zhong et al., 2023). Within this framework, the concept of urban-rural metabolism assumes a crucial role in deepening our comprehension of the intricate and dynamic relationships among various elements of human settlements and the environment. Urban-rural metabolism, as an interdisciplinary notion, facilitates an examination of how resources within settlements are utilized and waste is generated, alongside the accompanying societal, economic, and environmental challenges. Moreover, it endeavors to delineate how settlements utilize, transform, and discharge flows of materials, energy, and water (Baccini & Bruner, 2012). The concept of settlement metabolism was initially proposed by Abel Wolman as far back as 1965, and since then, there has been a growing inclination towards viewing urban metabolisms as interconnected and cyclical processes, prioritizing resource efficiency over linear models (Lucertini & Musco, 2020; Wang, 2022). This article aims to analyze Chencun Village in the Shunde District of Guangdong, China, as a representative case study of a *desakota* area. The objective is to present findings regarding water, energy, and material flows, while also providing a comprehensive overview of the case study area’s spatial and demographic characteristics, its position within cities, and the physical attributes of the settlement, including building types, land use patterns, infrastructure, and open spaces.

By 2006 and 2007 or thereabouts the world’s population of about 6.7 billion people crossed a threshold of 50 percent urban to 50 percent rural inhabitants by locale, rising to around 56 percent urban in 2023. During this transition, the urban population of China rose from a paltry 13 percent in 1950 to slightly above 56 percent. By 2050 these proportions seem likely to change globally to around 68 percent urban and 32 percent rural (Ritchie, et al., 2024). Presently there are at least four kinds of settlement coexistence. They are “compact central city areas”, “dispersed city and

peripheral areas” sometimes referred to as being suburban, “organic and informal settlements”, and “desakota” areas, particularly in east and southeast Asia. More specifically in the Chinese context desakota settlements or “township-village enterprises” form a significant part of otherwise rural areas. Although becoming more generally urban, as already noted, the number of rural townships remains slightly above 10,000 in number in 2020, though down lower than some 25,000 in 1979. Indeed, this divergence of smaller towns to more normal urban city pathways has been relatively late in coming to China, dating from as recently as 2000 (Kan & Chen, 2021).

The term “desakota” is from the Indonesian “desa” meaning village and “kota” meaning town and was coined by Terry McGee in the 1990s (McGee, 1991). Also, roughly synonymous with “Township-Village Enterprises” in the Chinese context, they have typically happened in Asia and were located at least initially outside peri-urban zones away from convenient daily commuting and often adjacent to arterial roads. Generally, they were and are characterized by relatively high population densities and adjacent intense agricultural development. They differ from rural areas per se because of their more urban living conditions. In China, they occurred primarily during the Reform Period of the 1980s and mostly in coastal areas such as Guangdong Province and they included enterprises usually sponsored by townships and villages. They also often accommodated substantial numbers of migrant workers and so-called “floating populations”. This usually comprised a rentier situation where villagers gained rental income from migrants working nearby in factories or within onsite village enterprises. Over time many of these settlements have become almost literally absorbed into burgeoning urban development, such as in Guangzhou and Shenzhen (Rowe, et al., 2022).

2. Materials and Methods

2.1. Context

An example of such a settlement coexistence and an urban-rural lifestyle can be found in Chencun Village in the Shunde District of Foshan in Guangdong Province as illustrated in Figure 1. Referred to as *Shuntak* in Cantonese, this district is a county-level city with an urban area of 806 square kilometers and a population of 2.5 million inhabitants. Renowned for various forms of agriculture from the late Ming through the Qing dynasties, it was a center of sericulture and silk production. In fact, the current Chencun Village remains agriculturally productive with a footprint covering much of 60 percent of the overall site with fresh flowers and trees, as depicted in Figure 2. Indeed, the proportional value of agricultural production in China, judging from 2016 data is the highest rate in the world depicted in Figure 3 (Adapted from Ritchie & Rosado, 2023). Also, as shown in Figure 4, the village, covering an area of 131 hectares, takes on a dispersed but contiguous overall planar form, mainly of residences often associated with district level roadways. Adjacent spaces are given over to plant and tree growing, with a large flower market located on Weixin Lou, a major arterial road cutting through the village from east to west. The population of the village is comprised of some 5,000 residents and a “floating population” of another 1,000 or so inhabitants, all across 1,781 residential units. Mostly these inhabitants are housed in three-and four-story dwellings, as depicted in Figure 5, with ground floors occupied by garages or commercial enterprises, particularly along major streets. Generally, the resident community is well off economically and also incorporates some small factory operations making needed hardware, alongside a primary school.

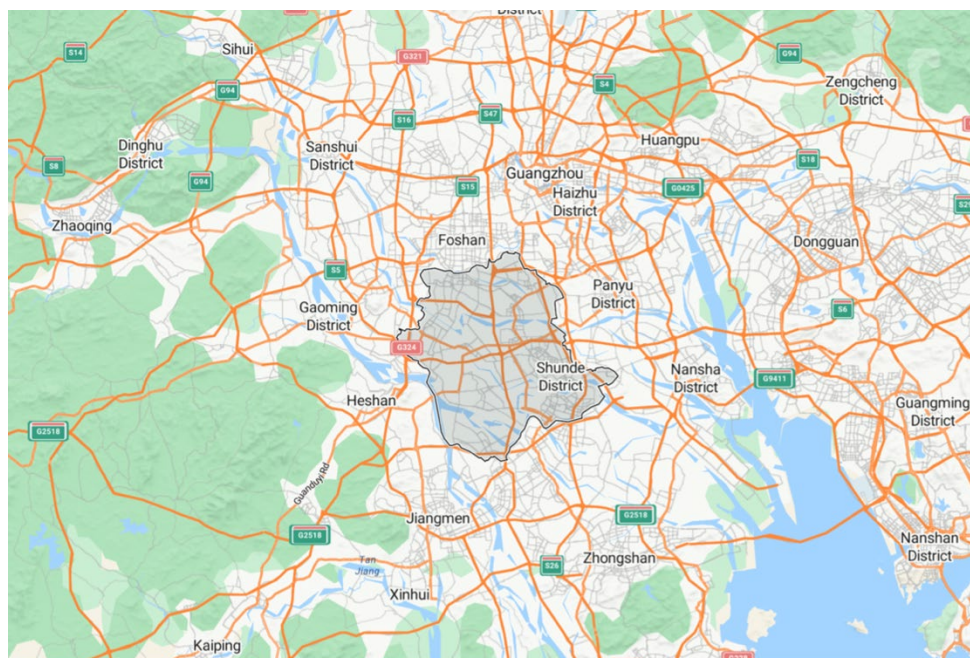


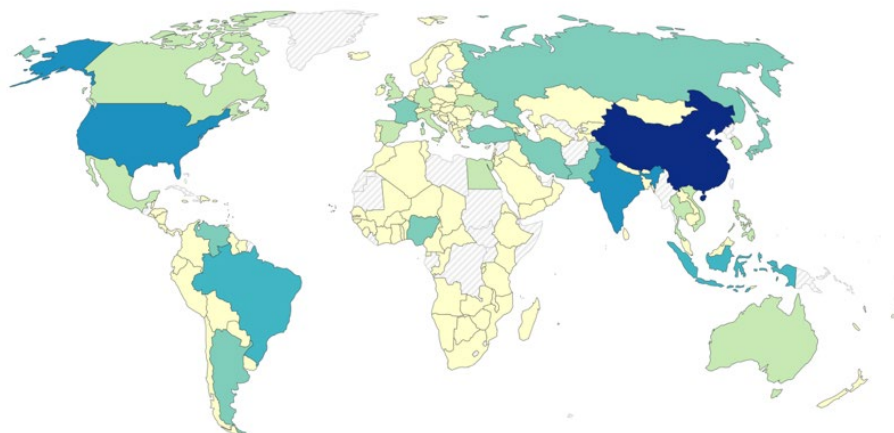
Figure 1. The Shunde District in the Context of Guangzhou and Guangdong Province, China.



Figure 2. Agricultural Production in Chencun Village, China.

Value of agricultural production, 2016

Gross production value of the agricultural sector, measured in current US\$.



Data source: Food and Agriculture Organization of the United Nations (2024) OurWorldInData.org/agricultural-production | CC BY

Figure 3. Worldwide Average of Agricultural Production, 2016. Adapted from “Agricultural Production” by Ritchie H. & Rosado P., 2023, Our World in Data. Data originally sourced from the Food and Agriculture Organization of the United Nations (FAO).

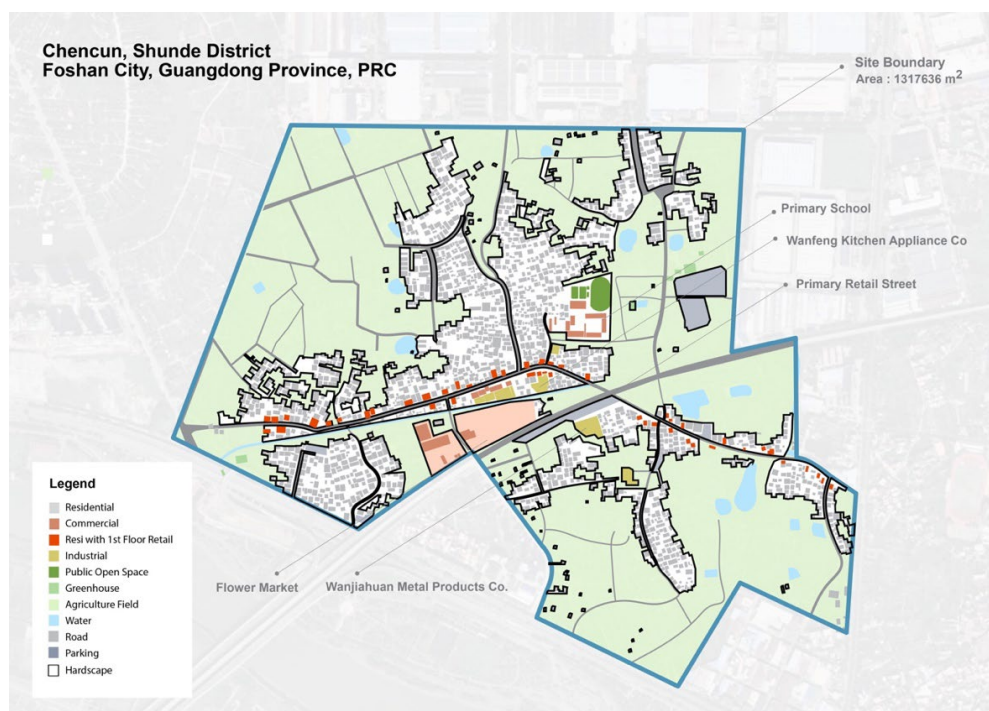


Figure 4. The Layout of Chencun Village, China.



Figure 5. Residential Buildings in Chencun Village, China.

2.2. Model Framing

With the apparent onset of the Anthropocene Era, concern for the metabolism of various kinds of settlement has risen appreciably. This metabolic aspect is manifest in the material from which the settlement is made and how these materials are refurbished and eventually disposed of and recycled, as well as stock flows of water and energy involved. In keeping with much earlier metabolic depictions of life dating back to the 16th century and earlier, research resulting in both conservation of mass and energy principles by the 18th century, more current accounts were mooted in 1965 by Abel Wolman (Wolman, 1965). Then links between the material character of the natural world and domains like the “Geosphere”, “Biosphere” and “Hydrosphere” could be forged with activities of the “Technosphere”, together with the residuals of spatial settlement production in the form of waste management and recycling potential. This could also be accomplished in a manner that directly reflected temporal variations on processes like deterioration and obsolescence (Baccini & Bruner, 2012). At root metabolism was bound up with the depiction, modeling, and analysis of flows of materials, water, and energy associated with human settlement. In addition, these flows could be conveniently represented through Sankey Diagrams, named after the pioneering work of Captain Sankey in 1898 in explaining the operation of the steam engine (Schmidt, 2008). Read from left to right, the flows of stocks emerge from natural domains and are manufactured into building materials and then deployed within settlement development and finally discarded and/or recycled. The proprietary software SankeyMATIC allows for relatively easy plotting of Sankey diagrams, though with the drawback of not representing circularity easily that needed to be overcome through obsolescence equations.

2.3. Data Sources and Interface

Data for the modeling exercises in this article covered at least seven broad categories. They were spatial and population data, construction data, transportation data, information regarding specific stocks of material, data about waste management and recycling, as well as about water and energy use. The types of sources involved were primarily governmental agencies though proprietary sources for particular kinds of materials are also available and relatively reliable. Overall, there were three kinds of data. The first used direct field observation and measurement. This usually concerned information about site uses, some population characteristics, and areas of coverage. Second, there was data specific to a particular locale and within the purview of that locale. For China use was made of available “open data” as well as standardized data sets for built-up areas of the county (Liu et al., 2015; Jiang et al., 2021). Third, there was data relying on proxies drawn from wider surrounding areas such as the city-wide scale. Rarely, if ever, data sources went beyond these levels of spatial resolution. Rough proportions among each of these three categories were around five to ten percent from direct observation, some twenty-five percent from local sources, and the

remainder involving broader proxies. All data, however, was clearly classified as to source, documented, and replicable.

Within each of the three types of stock-flow model depicted in this article, special interfaces have been developed, particularly for facilitation of data input using Excel (v.16.77), each employing a comparable framework and accounting method influenced by material flow analysis (MFA). To create a model of the metabolism of the avenue, mass conservation principle was used where the mass of inputs in a process equals the mass of outputs, plus a storage term (Doussard et al., 2024). m represents mass, along with equivalent units for energy and water, while time derivatives are indicated by dots. p and q denote the summation over input and output terms, respectively.

$$\sum_p \dot{m}_{\text{input}} = \sum_q \dot{m}_{\text{output}} + \dot{m}_{\text{storage}} \quad (1)$$

In the water model, for instance, these include information about the site and occupying population, residential, commercial, and public, as well as industrial and agricultural activities, along with green spaces. For the energy model interfaces apply again to site information and population characteristics, commercial, industrial, agricultural, and transport characteristics. For the material models, categories include site and population, construction of buildings and infrastructure, green spaces, production from agriculture and industry, activities and goods consumption, transport characteristics like various fleets, and waste, including recycling, composting, mining, and waste disposal as depicted in figure 6.

Finally, 11 percent was ascribed to transportation again reflecting the rather compact and “stay-at-home” nature of desakota settlement. Improvements in water use could be found in higher levels of gray water use, though the relatively low levels of its primary source in residential use is a constraint. Further shifts towards renewable sources of energy should also be encouraged. Finally, the defining characteristics of material stock-flows in metric tons per year are shown in Figure 9 with fully 85 percent drawn from the Geosphere, 11 percent from the Biosphere, and 4 percent from the Hydrosphere. With regard to land use, most at 85 percent was in residential and agricultural industrial use, including considerable amounts of clay in the pot planting of plants and trees, followed by 6 percent or so in commercial use and 4 percent in transportation. Moderate obsolescence rates meant that 85 percent of material flows remained annually as stock, with some 6 percent ending as collected waste. Of this 78 percent was sorted, 19 percent was otherwise recycled, and 2 percent was composted. Moreover, of the sorted waste fully 89 percent was mined and re-used, a frugality not uncommon to desakota forms of settlement (Cossu & Williams, 2015).

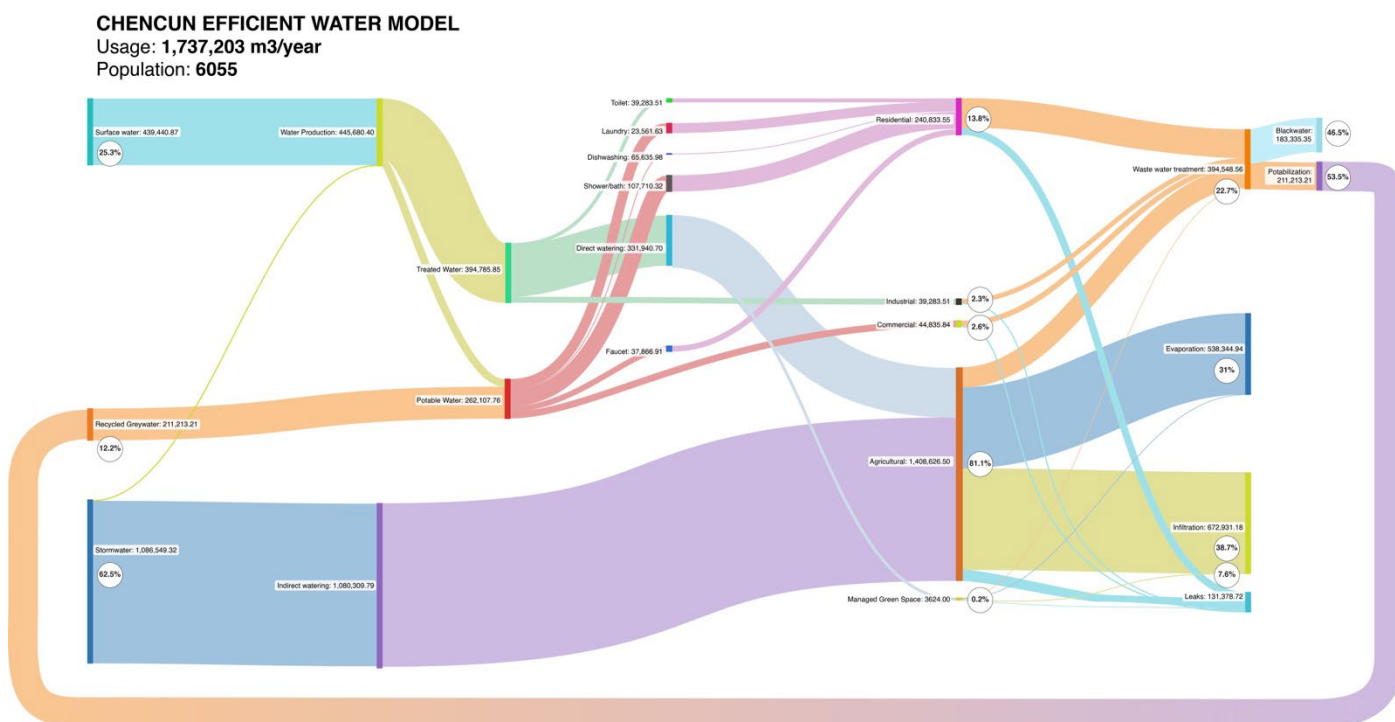


Figure 7. Sankey Diagram of Chencun Efficient Water Model.

CHENCUN ENERGY EFFICIENT MODEL

Usage: 265,330,593 kWh/year

Population: 6055

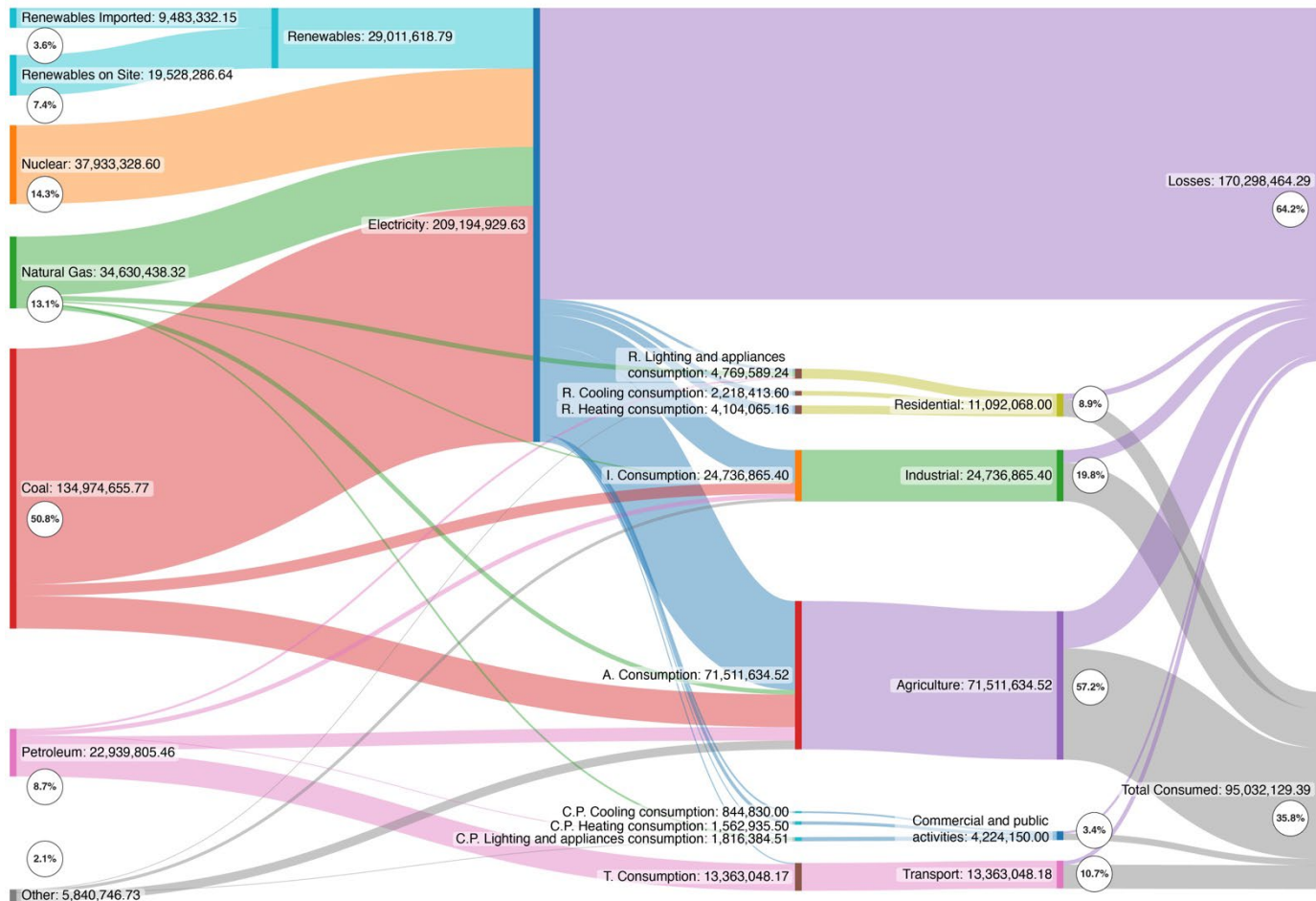


Figure 8. Sankey Diagram of Chencun Efficient Energy Model.

CHENCUN MATERIAL MODEL
 Usage: **705,961 ton/year**
 Population: **6055**
 Lifecycle of buildings: **35 years**
 Lifecycle of hardscape: **20 years**
 Lifecycle of roads: **15 years**
 Lifecycle of parking lots: **50 years**
 Lifecycle of railway lines: **50 years**

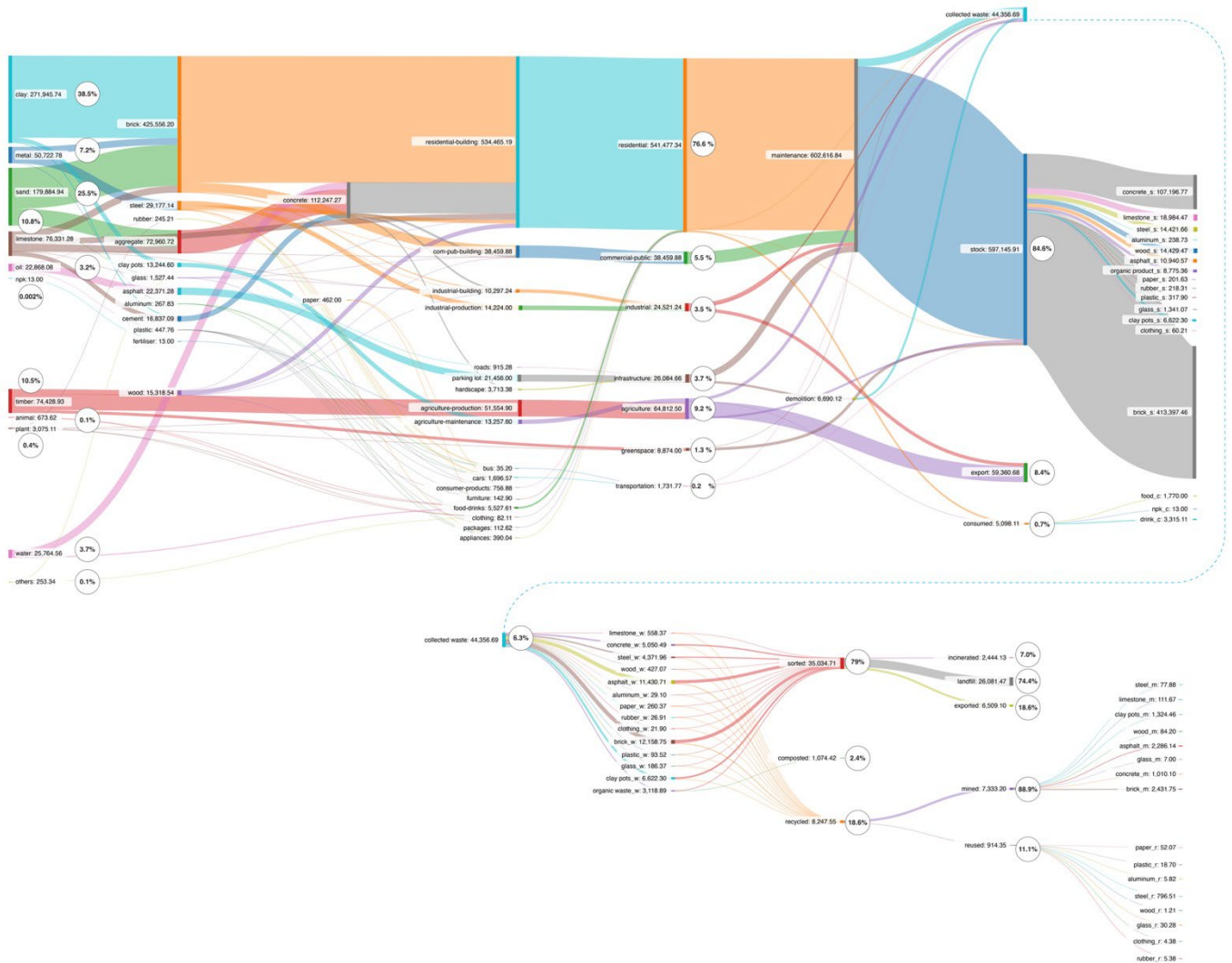


Figure 9. Sankey Diagram of Chencun Materials Model.

Compared to other forms of settlement coexistence, desakota areas perform relatively well metabolically and certainly in comparison to less agriculturally developed territories. Setting aside “informal settlement” and their relatively impoverished circumstances, Chencun’s material use is conservative at around 106 metric tons per inhabitant, compared to Paris’ compact inner area development at 117 and the US suburban or peripheral developments wasteful 246 tons per inhabitant. Similarly, applying standard multipliers for embodied energy in MJ/kg/yr. and embodied carbon on KgCo2/kg/yr. averages again show Chencun to be on the low side among other forms of settlement coexistence at around 4.0 or slightly less MJ/kg/yr. compared to Parisian compact forms at around 4.1 and the American peripheral development at 5.8 MJ/kg/yr. Clearly differing obsolescence rates come into play as well, with buildings in the compact example at something like 100 years compared to American peripheral development pegged at around 60 or so years, and somewhat less for Chencun at around 35 to 50 years. Roadway infrastructure by contrast is usually relatively stable at around 15 to 20 years, at least in this modeling analysis. To reiterate, all told Chencun and its desakota style of settlement is relatively conservative from a metabolic perspective. To the extent that improvements might be made they seem to lie in water and waste management, as well as more use of energy renewables as noted earlier. Also, the pursuit of circular functions in

Chencun from the present “cradle-to-grave” configuration to something like, for instance, McDonough and Braungart’s “cradle-to-cradle” biometric mimicking could be attempted further and even for the purpose of becoming a safer stopgap to more rampant compact and peripheral forms of development within China’s emerging Metropolitan Urban Regions (McDonough & Braungart, 2002; Rowe et al., 2022).

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