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Material Flow Analysis and the State of Circularity in ASEAN Economies

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Introduction

Navigating the significant challenges of growing material living standards, reducing poverty, and providing essential services of food, water, energy, housing, mobility, and education in ASEAN economies whiles ensuring resource efficiency, waste minimization and emission reduction is the core ambition of the 2030 Sustainable Development Agenda. Such an ambitious goal requires well-designed polices and setting of strategic priorities and will benefit from metrics and data about societal, economic, and environmental outcomes. A modern environmental and sustainability policy agenda can benefit from a sound understanding of material management and the degree of circularity of the economy. This report, for the first time, establishes comprehensive material flow accounts for the ASEAN region and its 10 constituent countries and assesses the current level of circularity.

We established a Circular Economy (CE) monitoring framework at the macro level, developed on existing research that proposed an extension of economy-wide Material Flow Account (MFA) by accounting for secondary materials flows and allow for monitoring socioeconomic loop closing in national economies (Haas et al., 2015). We applied the standard accounting methodology for national MFA defined in detail by the methodological guidelines made available by the European Statistical Office (Eurostat, 2018; Mayer et al., 2019).
Secondary materials (SM) refer to materials recovered through all forms of recycling, reuse, and remanufacturing. We built upon a systems and material standpoint of the economy, and as a substantial improvement, we based the assessment as far as possible on statistical data from the official environmental reporting system of UN for waste management in ASEAN countries (UN Environment, 2017)and systematically mass-balanced material inputs with waste flows stated in the different statistical sources.

The accounting framework traces materials by main material groups (Biomass, Fossil fuel, Metal ores, Non-metallic minerals, and Mixed and complex products) from their extraction to major application within the socioeconomic system and towards discard and either material recovery or deposition to nature as wastes and emissions.

Data on domestic extraction and trade of materials was obtained from the United Nations Environment Programme International Resource Panel Global Material Flows Database (UNEP IRP, 2022), while the information on emissions and waste are taken from (EDGAR, 2022; IFA, 2022).

Figure 1 illustrates material flows for Southeast Asia (ASEAN countries) in 2018. Average material use in Southeast Asia in 2018 was at 10.8 tonnes per capita of which 8.9 t/capita of raw materials originated from domestic extraction and 1.8 t/capita came from imports. 0.07 t/capita were secondary materials source form waste management and resource recovery activities in the region\.

2 tonnes of materials, mainly fossil fuels and biomass products were exported, and the remaining 8.8 t/capita of materials were processed domestically. 3.9 t/capita were used for food, animal feed and fibres and energy production and 4.9 t/capita for material use such as structural materials for buildings and infrastructure, vehicles, and long-lived consumer goods.

Energy materials, i.e., biomass and fossil fuels resulted in emissions to air of 1.7 tonnes per capita and liquid and solid waste of 2 tonnes per capita. Of the structural materials, 4 tonnes per capita were added to the stock of long lives infrastructure and consumer goods while 0.9 tonnes per capita were disposed as industrial and residential waste.

Overall, 3.8 t/capita were net additions to in-use stocks. Thus, 45% of all processed materials in 2018 increased the material stocks in the Southeast Asia and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops, but also requiring energy use for their operation.

The recycling rate of end-of-life waste of the whole of the ASEAN region in 2018 was 2.5% and the circularity rate was 0.8%. By comparison, the recycling rate of the European Union in 2014 was at 27.3% and the European Union Economy had a circularity rate of 7.5%.

The recycling rate is calculated as the proportion of recycling of end-of-life waste. Circularity is calculated as the proportion of recycling of processed materials.

A total of 3.3 t/capita of End-of-Life (EoL) waste resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of Municipal Solid Waste (MSW) for ASEAN countries is 22.5%. Domestic Processed Output (DPO) emissions to air accounted for 1.7 t/capita, of which 59% is originated from food, feed, and biomass energy, and the remaining (0.7 Gt) were from fossil energy carriers.

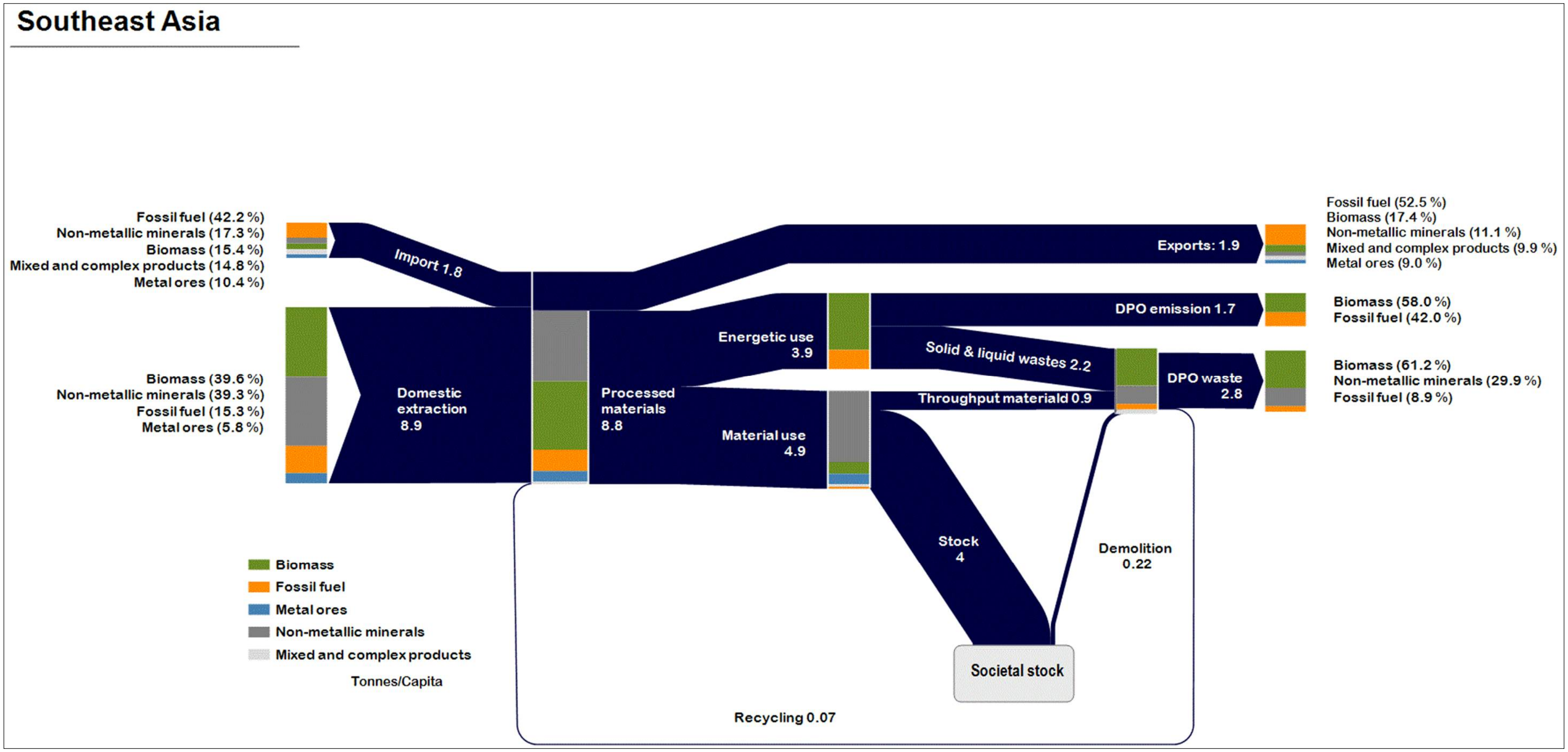

Figure 1: Material flows for Southeast Asia (ASEAN countries) in 2018.
*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars show the compositions (share of four main material groups in %).*
*Note that numbers may not always sum up to total due to rounding; t/capita*year = gigatons per year.*

Brunei Darussalam

Applying the CE monitoring framework to Brunei Darussalam shows that 34 t/capita of raw materials used in 2018 came from domestic extraction, 9 t/capita from net imports, and 0.05 t/capita from recycling (figure 2). Of the 16.7 t/capita of Processed Material, 8 t/capita were used to provide energy (more than double the ASEAN average) and 8.7 t/capita for material use (+75% higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 0.8 t/capita, while the majority of 7.9 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 7.5 t/capita have been net additions to in-use stocks (almost double the ASEAN average). Thus, half of all processed materials in 2018 increased the material stocks in the Brunei Darussalam and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 3.5 t/capita of EoL wastes (4% higher than the ASEAN average) were from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Brunei Darussalam is 10.5% (almost half of the ASEAN average).

DPO emissions to air accounted for 5.8 t/capita (3 times higher than the ASEAN average), which is dominated by emissions from fossil energy carriers (97%).

Insights from the analysis of Brunei Darussalam's 2018 material flows:

- Processed materials (both for energy and material use) in Brunei Darussalam were considerably higher than the ASEAN average. This is due to the relevance of oil exports to the country's economy.
- Net additions to in-use stocks were significantly higher, almost double, than the ASEAN average.
- DPO emissions are dominated by emissions from fossil energy carriers.
- 10.5% of MSW generated in Brunei Darussalam was recovered for recycling.
- Total biomass inputs are low, suggesting the country's demand for biomass is covered through imports of concentrated biomass, e.g. importing animal products rather than raising livestock on domestically produced pasture and feeds.

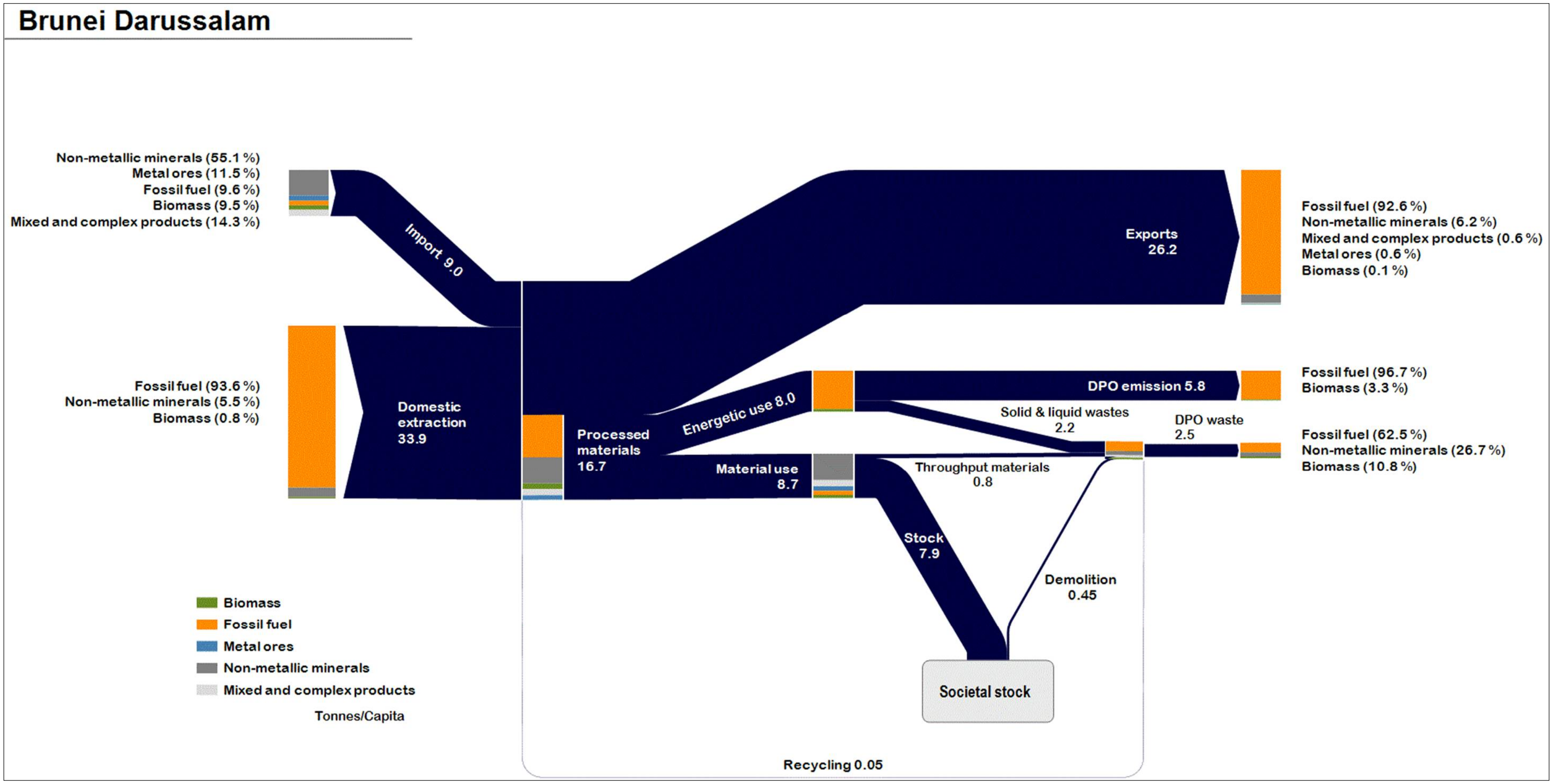

Figure 2: Material flows for Brunei Darussalam in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Cambodia

Applying the CE monitoring framework to Cambodia shows that 6.5 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 0.7 t/capita from net imports, and 0.04 t/capita from recycling (figure 3). Of the 7.1 t/capita of Processed Material, 2.9 t/capita were used to provide energy (24% less than the ASEAN average) and 4.1 t/capita for material use (16% less than the ASEAN average). Throughput materials, including extractive waste, accounted for 0.9 t/capita, while the majority of 3.2 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 3.1 t/capita have been net additions to in-use stocks (18% lower than the ASEAN average). Thus, 43% of all processed materials in 2018 increased the material stocks in Cambodia and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 3.1 t/capita of EoL wastes (5% lower than the ASEAN average) came from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Cambodia is 20.3% (similar to the ASEAN average).

DPO emissions to air accounted for 0.8 t/capita (51% less than the ASEAN average), which is dominated by emissions from food, feed, and biomass energy (95%).

Insights from the analysis of Cambodia's 2018 material flows:

- Processed materials (both for energy and material use) in Cambodia were slightly lower (24% and 16%) than the ASEAN average.
- Net additions to in-use stocks and EoL Wastes in Indonesia were slightly lower than the ASEAN average.
- DPO emissions are dominated by emissions from food, feed, and biomass energy.
- In 2018, 20.3% of MSW generated in Cambodia was recovered for recycling.
- There is large biomass extraction, though not large in per capita terms, with a very small proportion of biomass exports. This suggests a significant dependence on subsistence agriculture in Cambodia.
- The low levels of imports, exports, and fossil fuel use suggest that the economy could benefit from better integration with regional and international markets.

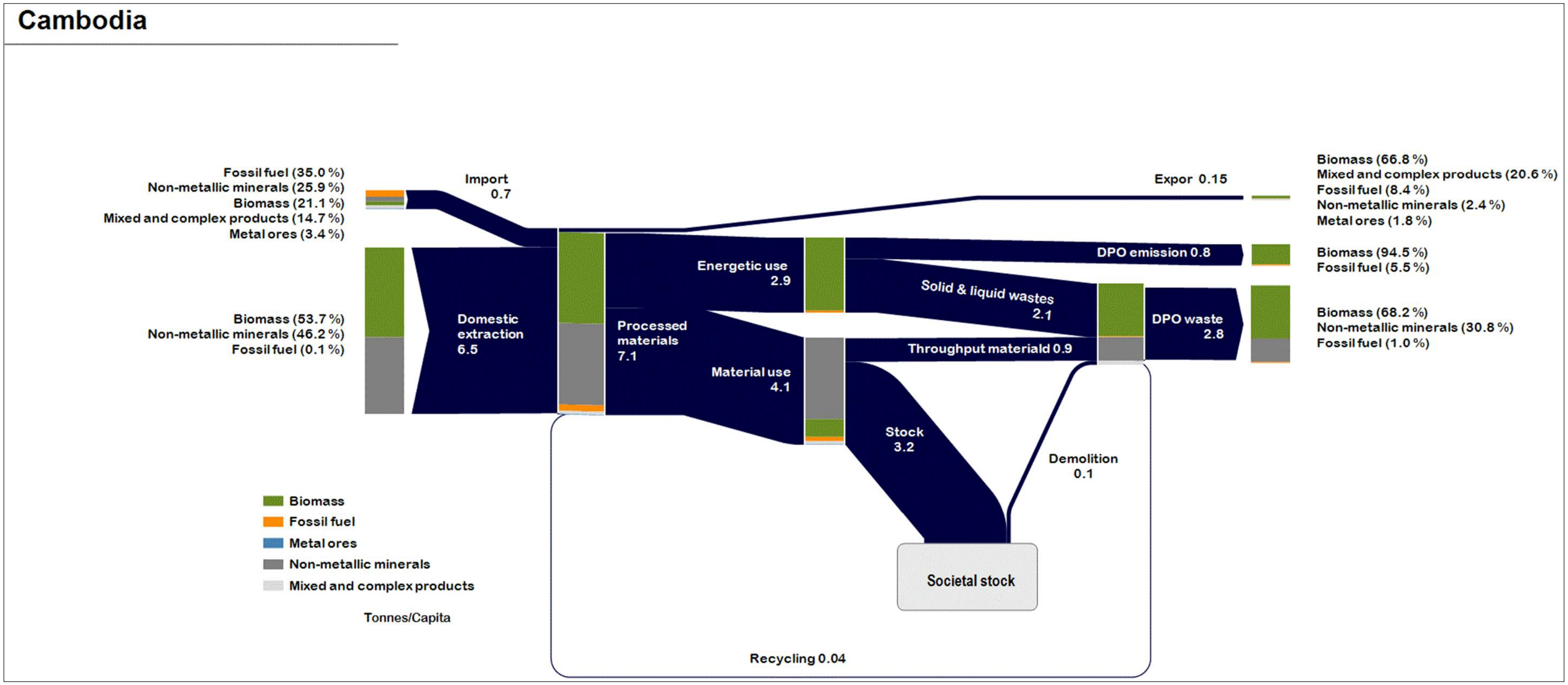

Figure 3: Material flows for Cambodia in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Indonesia

Applying the CE monitoring framework to Indonesia shows that 8.1 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 0.7 t/capita from net imports, and 0.05 t/capita from recycling (figure 4). Of the 6.6 t/capita of Processed Material, 3.2 t/capita were used to provide energy (17% less than the ASEAN average) and 3.4 t/capita for material use (30% less than the ASEAN average). Throughput materials, including extractive waste, accounted for 0.9 t/capita, while the majority of 2.5 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 2.3 t/capita have been net additions to in-use stocks (37% lower than the ASEAN average). Thus, nearly one-third of all processed materials in 2018 increased the material stocks in Indonesia and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 2.9 t/capita of EoL wastes (13% lower than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Cambodia is 22.5% (similar to the ASEAN average).

DPO emissions to air accounted for 1.4 t/capita (18% less than the ASEAN average), of which 0.9 t/capita were from food, feed, and biomass energy, and 0.5 t/capita from fossil energy carriers.

Insights from the analysis of Indonesia's 2018 material flows:

- Processed materials (both for energy and material use) were lower (17% and 30%) than the ASEAN average.
- Net additions to in-use stocks in Indonesia were also lower than the ASEAN average.
- A significant portion of DPO emissions came from food, feed, and biomass energy (64%).
- 22.5% of the MSW generated in Indonesia was recovered for recycling.
- Indonesia has very high fossil fuel exports dominated by coal. The country is the world's largest thermal coal exporter, and most of the coal is exported with minimal processing.
- Processed materials are relatively low, but their composition (fossil fuel and metals) indicates the presence of significant industrialisation processes.
- Most of the domestic extraction of metal ores, i.e. copper, gold and more recently nickel, is largely exported as either concentrates or refined metals. Most of the apparent domestic consumption of metal ores corresponds to waste in the form of mine tailings rather than material added to stocks. Imports of metal would go overwhelmingly to stocks.

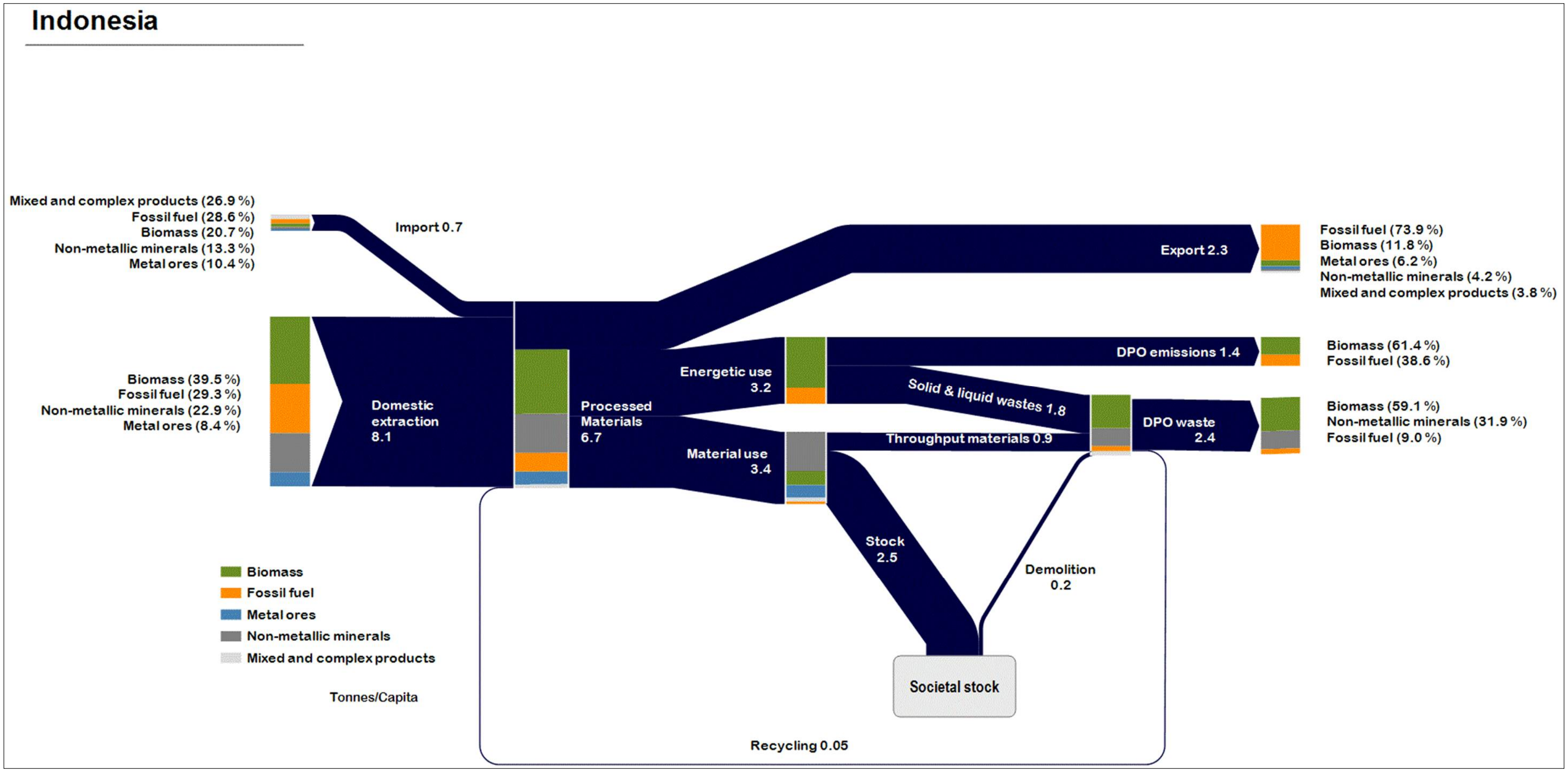

Figure 4: Material flows for Indonesia in 2018.
*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*
*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Lao PDR

Applying the CE monitoring framework to Lao PDR shows that 14.4 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 0.7 t/capita from net imports, and 0.06 t/capita from recycling (figure 5). Of the 14.3 t/capita of Processed Material, 6.6 t/capita were used to provide energy (71% higher than the ASEAN average) and 7.7 t/capita for material use (58% higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 1.3 t/capita, while the majority of 6.4 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 6.2 t/capita have been net additions to in-use stocks (66% higher than the ASEAN average). Thus, 43% of all processed materials in 2018 increased the material stocks in the Lao PDR and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 5.8 t/capita of EoL wastes (76% higher than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Lao PDR is 20.7% (slightly lower than the ASEAN average).

DPO emissions to air accounted for 2.3 t/capita (37% higher than the ASEAN average), of which 1 t/capita originated from food, feed, and biomass energy, and 1.3 t/capita from fossil energy carriers.

Insights from the analysis of Lao DPR's 2018 material flows:

- Processed materials (both for energy and material use) were considerably higher (more than 58%) than the ASEAN average.
- Net additions to in-use stocks and EoL wastes in Lao PDR were significantly higher (more than 66%) than the ASEAN average.
- The DPO emissions came almost equally from food, feed, biomass and fossil energy carriers.
- In 2018, 20.7% of MSW generated in Lao PDR was recycled.
- The relatively high levels of fossil fuel production are associated with mining lignite to produce electricity for export to Thailand. Lignite is one of the most CO_2 intensive forms of electricity production.
- Fossil fuels are transformed entirely into energy before export. Therefore, it does not show up on the exports side. This transformation prior to export gives the exact opposite effect of what we often see with fossil fuels, e.g. Brunei and Indonesia, where physical exports of the material see most of the DE tonnage retained with the exported good/service of value.
- The country's domestic use of metal ores going to societal stock in the graph is most likely going to waste as tailings.

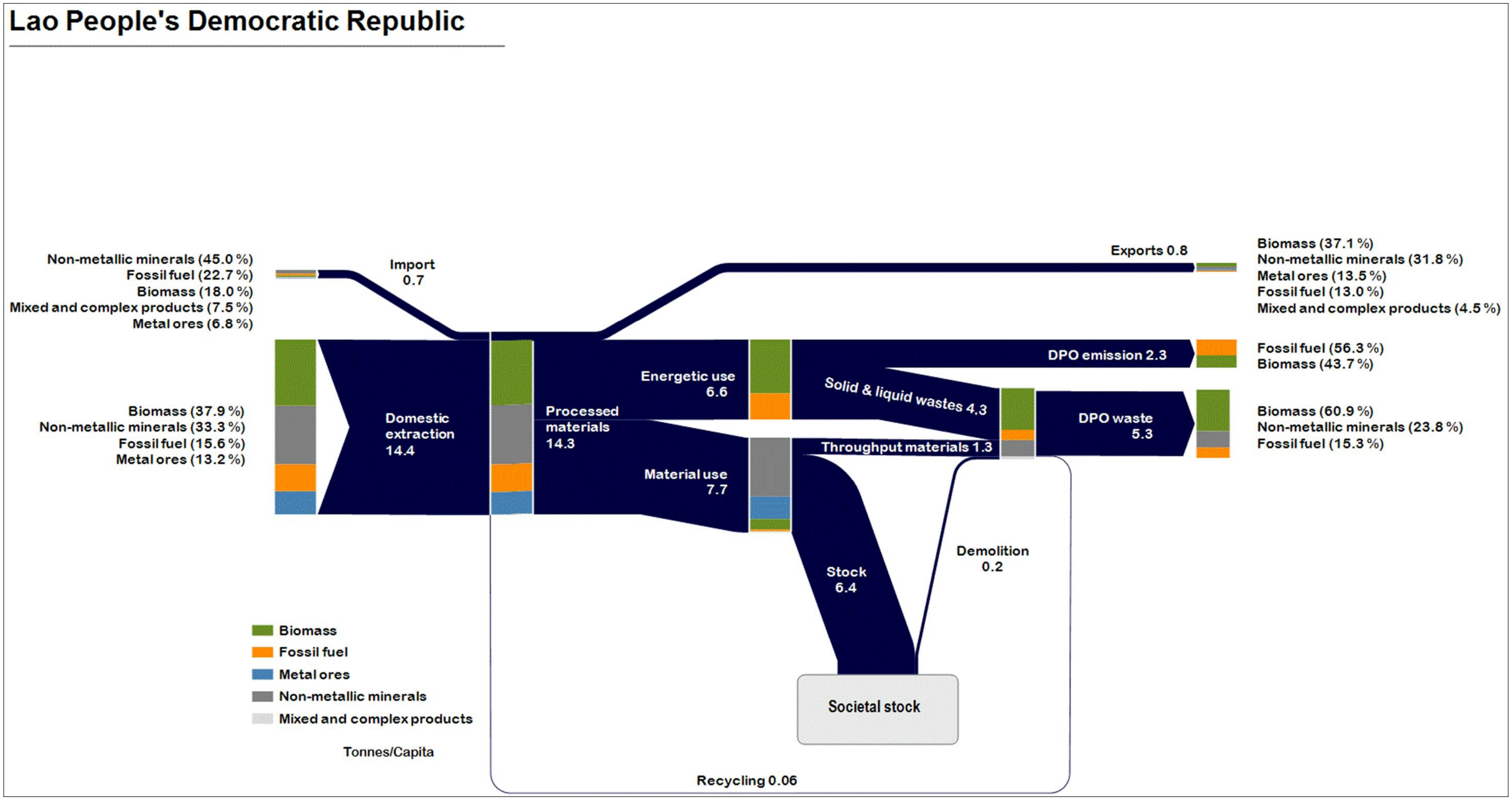

Figure 5: Material flows for Lao PDR in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Malaysia

Applying the CE monitoring framework to Malaysia shows that 21.4 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 6.6 t/capita from net imports, and 0.09 t/capita from recycling (figure 6). Of the 21.6 t/capita of Processed Material, 10.7 t/capita were used to provide energy (around 3 times higher than the ASEAN average) and 10.8 t/capita for material use (more than double the ASEAN average). Throughput materials, including extractive waste, accounted for 1.1 t/capita, while the majority of 9.7 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 9.4 t/capita have been net additions to in-use stocks (more than double the ASEAN average). Thus, 43% of all processed materials in 2018 increased the material stocks in Malaysia and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 6.9 t/capita of EoL wastes (more than double the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Malaysia is 22.9% (slightly higher than the ASEAN average).

DPO emissions to air accounted for 5.2 t/capita (three times higher than the ASEAN average), of which 3 t/capita originated from food, feed, and biomass energy, and 2.2 t/capita from fossil energy carriers.

Insights from the analysis of Malaysia's 2018 material flows:

- Processed materials (both for energy and material use) were significantly higher (more than triple) than the ASEAN average.
- Net additions to in-use stocks per capita and EoL wastes per capita in Malaysia were also significantly higher than the ASEAN average.
- The DPO emissions came almost similarly from food, feed, biomass and fossil energy carriers.
- In 2018, 22.9% of MSW generated in Malaysia was recovered for recycling.
- The higher level of total throughput, combined with a much higher level of mixed/complex product exports, is suggestive of a higher level of economic development than most other ASEAN countries.

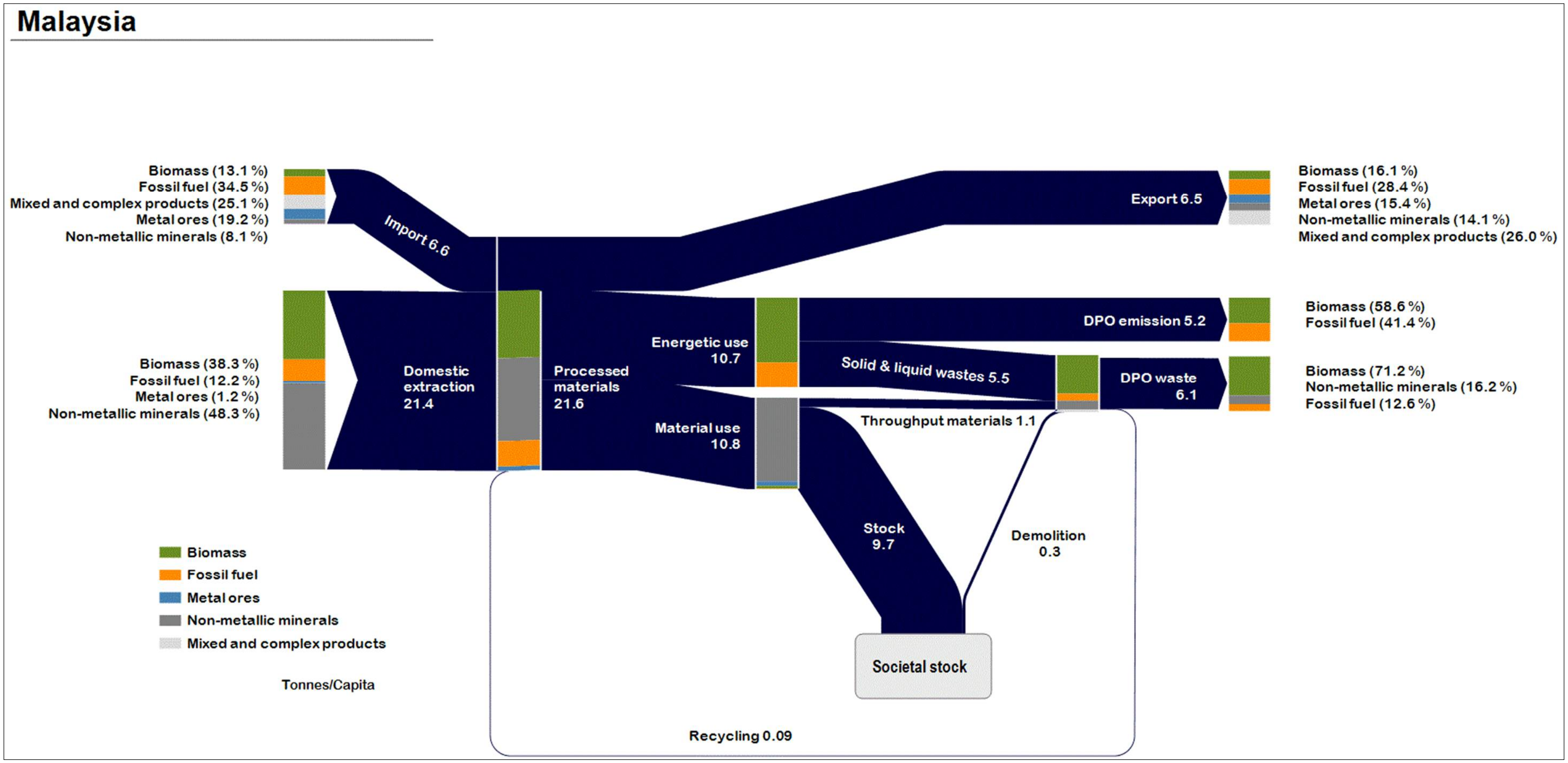

Figure 6: Material flows for Malaysia in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Myanmar

Applying the CE monitoring framework to Myanmar shows that 6.1 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 0.5 t/capita from net imports, and 0.03 t/capita from recycling (figure 7). Of the 6.3 t/capita of Processed Material, 3.6 t/capita were used to provide energy (7% less than the ASEAN average) and 2.6 t/capita for material use (46% less than the ASEAN average). Throughput materials, including extractive waste, accounted for 0.7 t/capita, while the majority of 1.9 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 1.7 t/capita have been net additions to in-use stocks (52% lower than the ASEAN average). Thus, 26% of all processed materials in 2018 increased the material stocks in Myanmar and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 3.7 t/capita of EoL wastes (10% higher than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Myanmar is 14% (significantly lower than the ASEAN average).

DPO emissions to air accounted for 0.8 t/capita (52% less than the ASEAN average), which is dominated by emissions from food, feed, and biomass energy (87%).

Insights from the analysis of Myanmar's 2018 material flows:

- Processed materials (both for energy and material use) were slightly lower than the ASEAN average.
- Net additions to in-use stocks per capita were significantly lower than the ASEAN average, while EoL waste per capita was close to the ASEAN average.
- The majority of DPO emissions came from food, feed, and biomass energy.
- In 2018, 14% of MSW generated in Myanmar was recovered for recycling.
- The structure of the material flow diagram indicates low imports and exports and fossil fuel use. This, in combination with the large share of biomass production and use, indicates the prevalence of subsistence agriculture.
- Metal ores DE in Myanmar is dominated by copper, so like in Laos and Indonesia, most DE goes to waste rather than stocks.

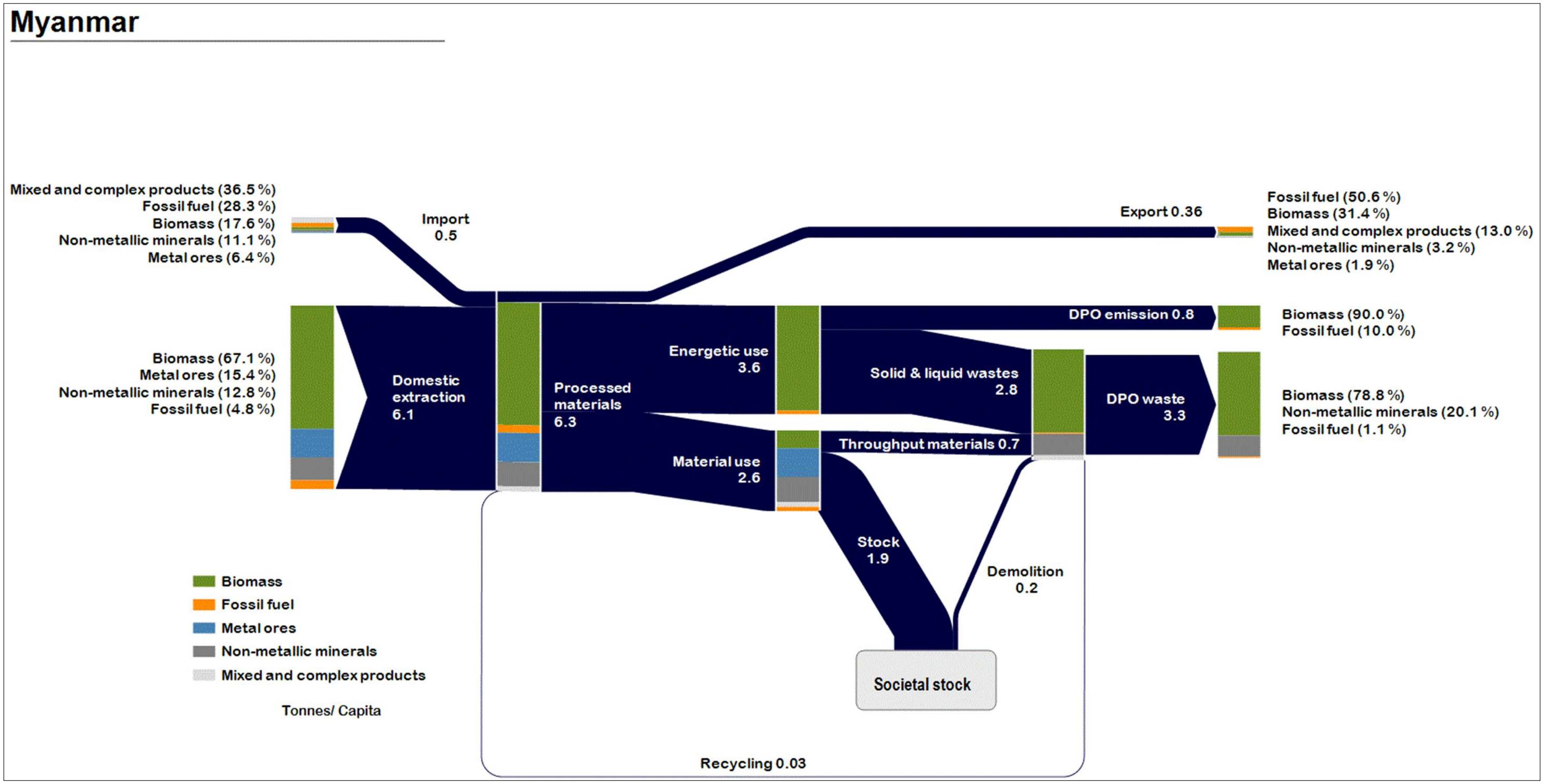

Figure 7: Material flows for Myanmar in 2018.
*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*
*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Philippines

Applying the CE monitoring framework to the Philippines shows that 7.4 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 1.1 t/capita from net imports, and 0.03 t/capita from recycling (figure 8). Of the 8.1 t/capita of Processed Material, 2.2 t/capita were used to provide energy (43% less than the ASEAN average) and 5.9 t/capita for material use (20% higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 0.8 t/capita, while the majority of 5.1 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 4.9 t/capita have been net additions to in-use stocks (30% higher than the ASEAN average). Thus, 60% of all processed materials in 2018 increased the material stocks in the Philippines and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 2.3 t/capita of EoL wastes (30% lower than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for the Philippines is 12.2% (almost half the ASEAN average).

DPO emissions to air accounted for 0.9 t/capita (46% less than the ASEAN average), of which 0.6 t/capita originated from food, feed, and biomass energy, and 0.3 t/capita from fossil energy carriers.

Insights from the analysis of the Philippines' 2018 material flows:

- While processed materials for energy use were lower compared to the ASEAN average (43%), the required material is 20% higher than the ASEAN average.
- Net additions to in-use stocks per capita were significantly higher than the ASEAN average (30%), whereas EoL waste per capita was 30% lower than the ASEAN average.
- The majority of DPO emissions came from food, feed, and biomass energy (66%).
- In 2018, 12.2% of MSW generated in the Philippines was recovered for recycling.
- The share of non-metallic minerals in domestic material extraction is very large. This is consistent with more detailed data showing that the extraction of sand, gravel and crushed rock for construction has quadrupled over the last decade (UNEP IRP, 2022). This may be linked to significant infrastructure build-up.
- Metal ores DE in the Philippines is dominated by copper, gold, and nickel, so like in Laos and Indonesia, most DE of ores goes to waste rather than stocks.

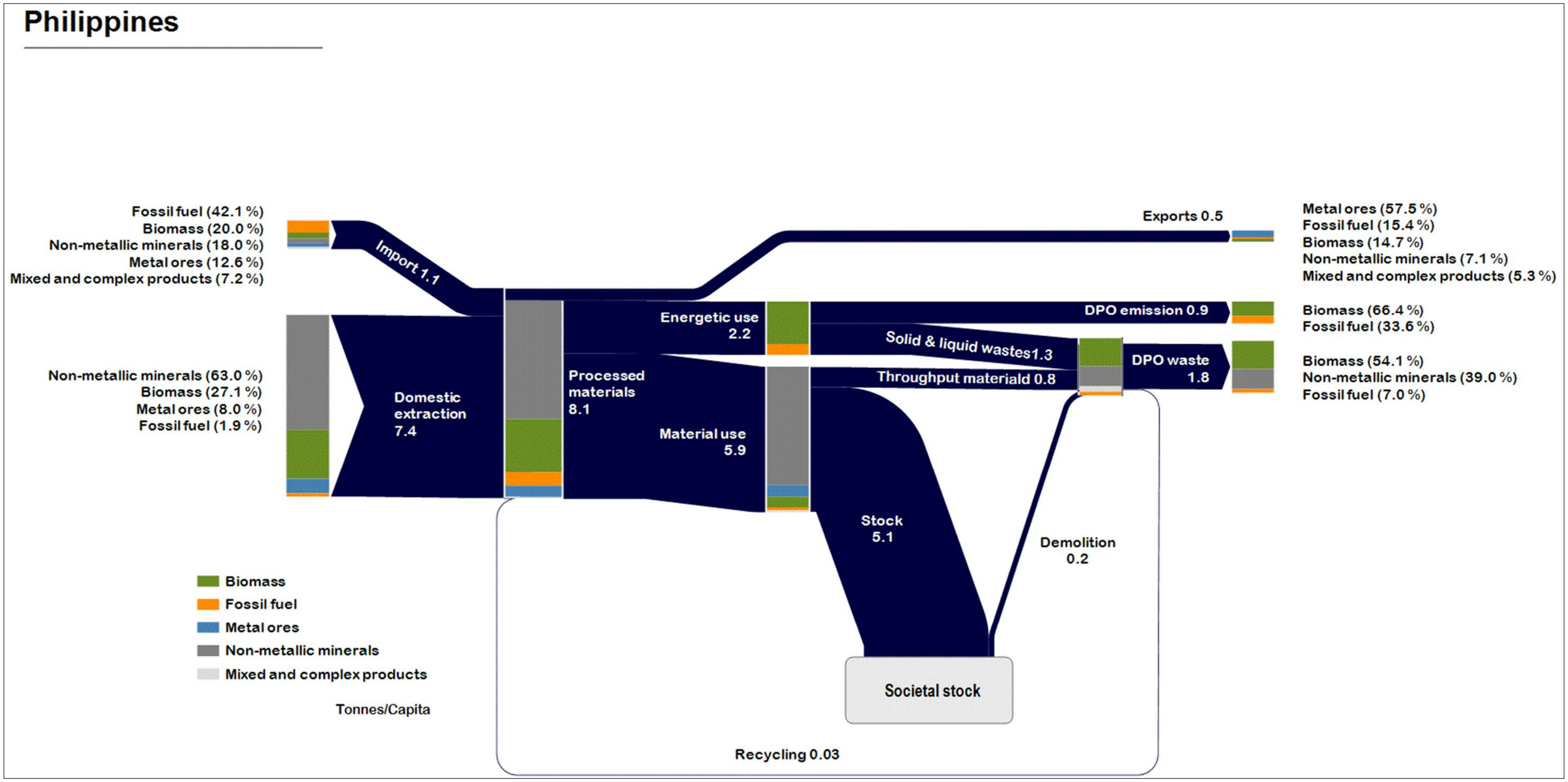

Figure 8: Material flows for Philippines in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to total due to rounding; t/capita*year = tons per capita per year.*

Singapore

Applying the CE monitoring framework to Singapore shows that 1.2 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 51.5 t/capita from net imports, and 0.8 t/capita from recycling (figure 9). Of the 30.4 t/capita of Processed Material, 11.5 t/capita were used to provide energy (3 times higher than the ASEAN average), and 18.2 t/capita for material use (around 4 times higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 2.2 t/capita, while the majority of 16 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 15.3 t/capita have been net additions to in-use stocks (four times the ASEAN average). Thus, half of all processed materials in 2018 increased the material stocks in Singapore and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 4.9 t/capita of EoL wastes (44% higher than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Singapore is 51.6% (more than double the ASEAN average).

DPO emissions to air accounted for 9.5 t/capita (around 6 times higher than the ASEAN average), which is dominated by emissions from fossil energy carriers (98%).

Insights from the analysis of Singapore's 2018 material flows:

- Processed materials for both energy and material use were 3-4 times higher than the ASEAN average.
- Net additions to in-use stocks per capita (around 16 tonnes per capita) were also four times higher than the ASEAN average (30%), whereas EoL wastes per capita were 44% higher than the ASEAN average.
- The majority of DPO emissions came from fossil energy carriers.
- In 2018, 51.6% of MSW generated in Singapore was recovered for recycling.
- Most materials needed in Singapore are imported. For instance, Singapore imports over 90% of the food consumed. This is shown by the remarkably low biomass extracted in the country and the high levels of both import and export of fossil fuels.
- Fossil fuels are a key component of the economy. Petroleum and other liquids represent 86% of Singapore's primary energy consumption, followed by natural gas at 13%. Coal and renewable energy sources account for the remaining 1% of primary energy consumption. This presents opportunities and challenges to reducing domestic emissions.
- The low share of DE in non-metallic minerals is remarkable, which emphasises Singapore's reliance on other countries for all significant material inputs.

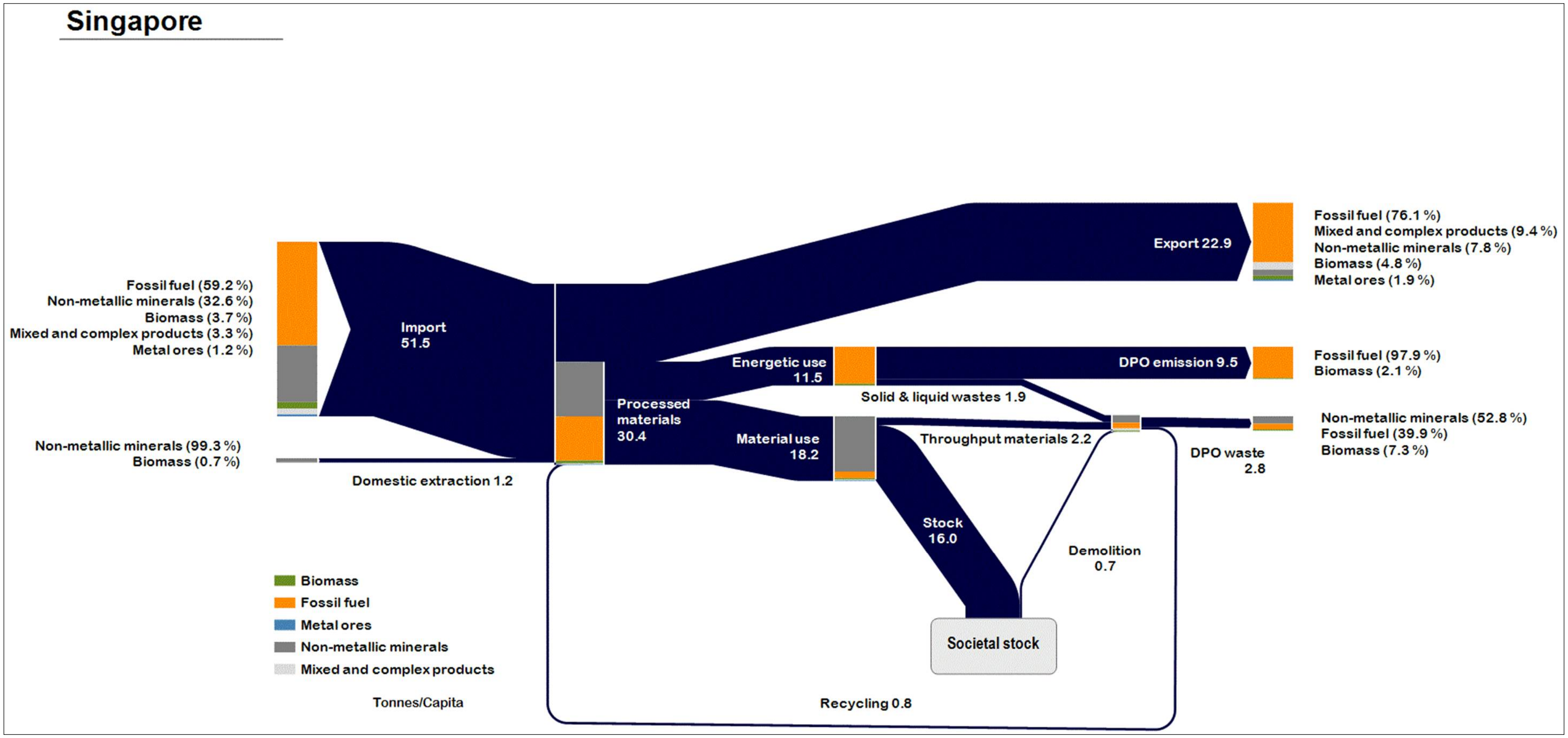

Figure 9: Material flows for Singapore in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Thailand

Applying the CE monitoring framework to Thailand shows that 11.3 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 2.7 t/capita from net imports, and 0.14 t/capita from recycling (figure 10). Of the 11.9 t/capita of Processed Material, 6.8 t/capita were used to provide energy (77% higher than the ASEAN average) and 4.9 t/capita for material use (2% higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 1.2 t/capita, while the majority of 3.8 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 3.5 t/capita have been net additions to in-use stocks (6% lower than the ASEAN average). Thus, around 30% of all processed materials in 2018 increased the material stocks in Thailand and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops but also requiring energy use for their operation.

A total of 5 t/capita of EoL wastes (48% higher than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Thailand is 34.9% (50% higher than the ASEAN average).

DPO emissions to air accounted for 3.3 t/capita (96% higher than the ASEAN average), of which 1.8 t/capita originated from food, feed, and biomass energy, and 1.5 t/capita from fossil energy carriers.

Insights from the analysis of Thailand's 2018 material flows:

- Processed materials for energy were significantly higher than the ASEAN average (77%), while the required materials were only 2% higher than the ASEAN average.
- Net additions to in-use stocks per capita (4 tonnes per capita) were close to the ASEAN average, whereas EoL wastes per capita were 48% higher than the ASEAN average.
- The majority of DPO emissions came from food, feed, and biomass energy.
- In 2018, 34.9% of MSW generated in Thailand was recovered for recycling.
- Thailand has the highest per capita material input of the large ASEAN countries, it produces significant exports, including mixed and complex products, and its economy generates sufficient export income to cover significant imports, including most of its fossil fuel needs.
- Thailand is unusual in getting a significant amount of electricity (>10%) directly imported from Lao PDR, from both renewable (hydro) and high CO_2 sources.
- The Thai economy used around 14.14 tons of material per capita in 2018. This number includes domestic extraction, imports (which are mainly imports of fossil fuels) and recycling. Around half of the domestic production is biomass, and 41% is non-metallic materials.
- Almost 60% of the materials processed in the country are for the generation of energy using food, fodder, and fossil fuels.

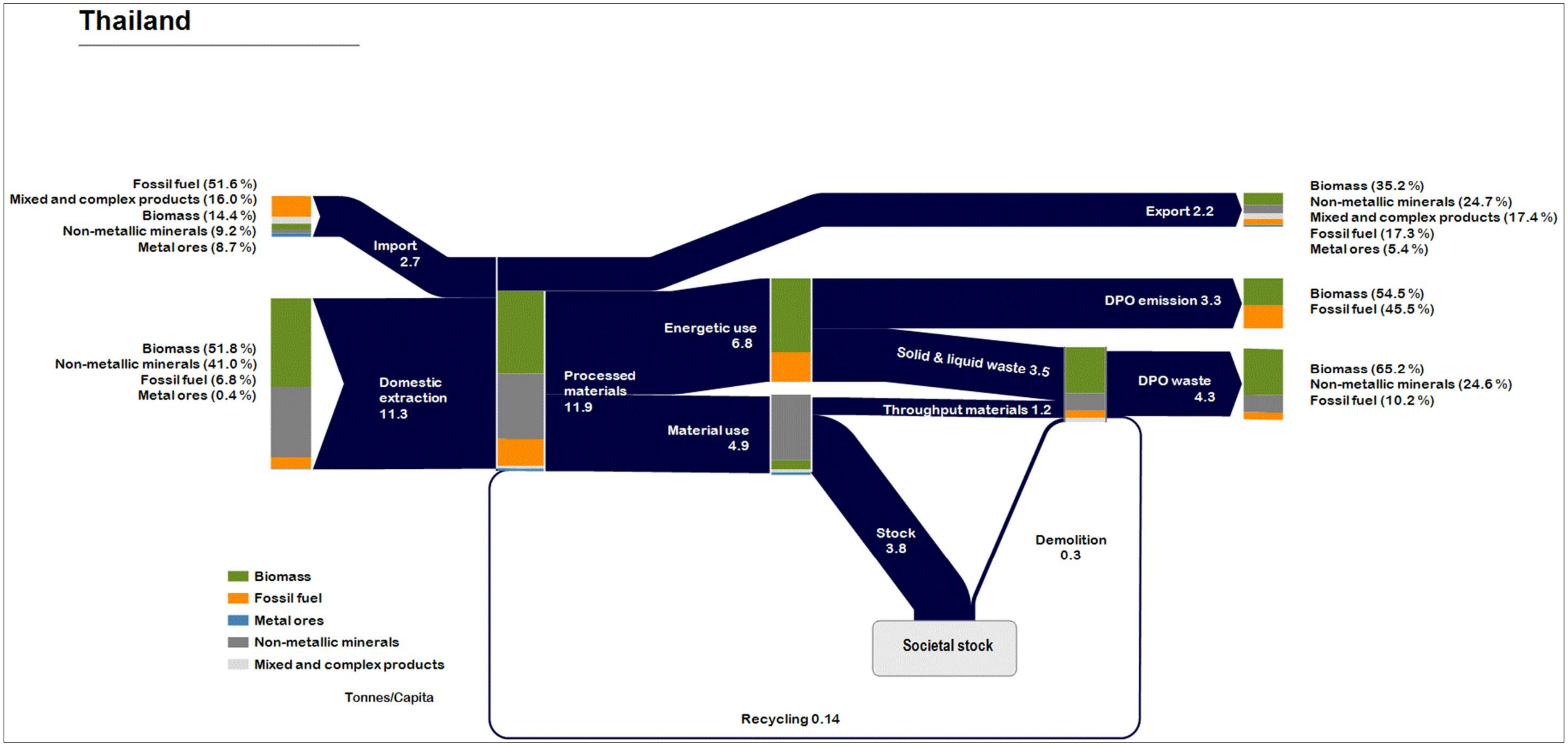

Figure 10: Material flows for Thailand in 2018.
*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*
*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

Viet Nam

Applying the CE monitoring framework to Viet Nam shows that 9 t/capita of raw materials, which were used in 2018, originated from domestic extraction, 1 t/capita from net imports, and 0.14 t/capita from recycling (figure 11). Of the 9.1 t/capita of Processed Material, 2.7 t/capita were used to provide energy (29% less than the ASEAN average) and 6.3 t/capita for material use (29% higher than the ASEAN average). Throughput materials, including extractive waste, accounted for 1.1 t/capita, while the majority of 5.2 t/capita were used to expand and maintain material in-use stocks of buildings, infrastructure, and other long-lived material products.

Overall, 4.9 t/capita have been net additions to in-use stocks (30% higher than the ASEAN average). Thus, 54% of all processed materials in 2018 increased the material stocks in the Viet Nam and will remain in use for years to decades, thereby shaping future waste flows and potentials for closing material loops, but also requiring energy use for their operation.

A total of 2.9 t/capita of EoL wastes (30% less than the ASEAN average) resulted from demolition and discard, throughput materials, and solid & liquid wastes from energetic use. The average recycling rate of MSW for Viet Nam is 16% (50% higher than the ASEAN average).

DPO emissions to air accounted for 1.1 t/capita (33% less than the ASEAN average), of which 0.66 t/capita originated from food, feed, and biomass energy, and 0.44 t/capita from fossil energy carriers.

Insights from the analysis of Viet Nam's 2018 material flows:

- Processed materials for energy were 30% less than the ASEAN average, while the material use was 30% higher than the ASEAN average.
- Net additions to in-use stocks per capita were also 30% higher than the ASEAN average (30%), while on the other hand, EoL waste per capita was 30% lower than the ASEAN average.
- The majority of DPO emissions came from food, feed, and biomass energy.
- In 2018, 16% of MSW generated in Viet Nam was recovered for recycling.
- Similar to the Philippines, non-metallic minerals account for a large share of the domestic extraction of materials. This suggests significant infrastructure and manufacturing build up in the country.

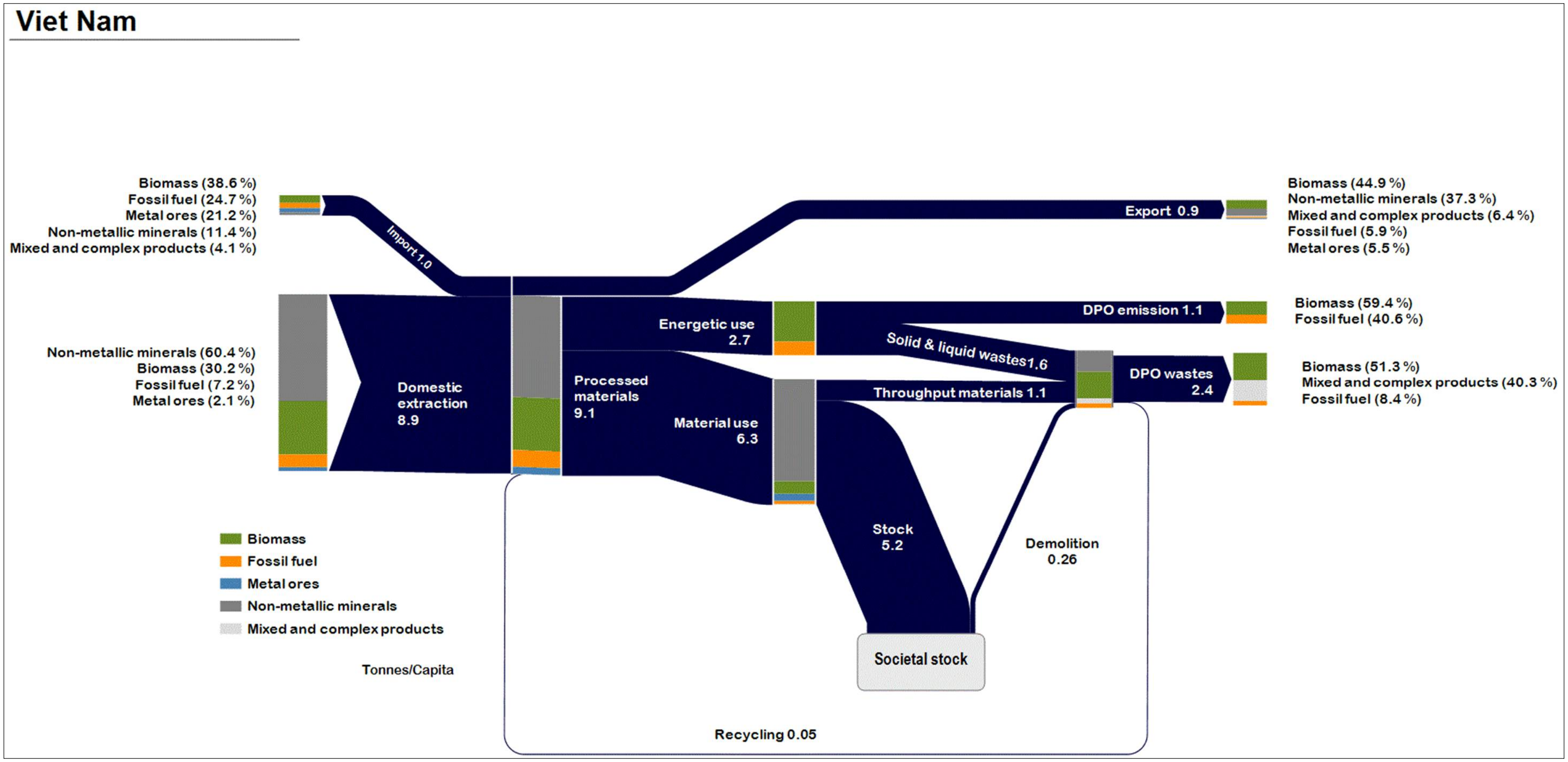

Figure 11: Material flows for Viet Nam in 2018.

*In this Sankey diagram, the width of the arrows is proportional to the size of material flows (dark blue); the numbers show the size of the material flows in t/capita*year and the bars their composition (share of four main material groups in %).*

*Note that numbers may not always sum up to the total due to rounding; t/capita*year = tons per capita per year.*

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