Socio-economic Material Metabolism of the Philippines
フィリピンにおける社会経済に関わる物質代謝

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Summary

Technological advancements enable to transform materials and energy from natural environment into usable forms, to improve and develop society and economy. Such advancement, together with demographic change and economic growth resulted in fast growing global material consumption. Growing material requirements of socio-economic processes, however, are responsible for the degradation of natural environment through intensified resource extraction, and increasing waste disposal and emissions.

Countries are now confronted with growing challenges of improving the economy while protecting the environment. The very economically dynamic Asia-Pacific region has become crucially important for global material use that is reflected in the increased volume of scholarly studies of socio-economic metabolism and material flows for the region and for specific countries. However to date, many countries have only been examined as constituents of global regions, obscuring country-specific details which may be key to understanding patterns of material needs and economic development. This PhD research project aims to fill this gap and contribute to the body of knowledge in the field of industrial ecology through an in-depth examination of the material flows and stocks mobilized by economic development and policy in the Philippines. This serves as a case study for the socio-metabolic transition of a medium-sized emerging economy in the Asia-Pacific region and perhaps beyond. This research develops a full material flow account for the Philippines to establish the trends, identify driving forces, monitors progress in

技術の進歩により，天然資源を利用可能な状態に変換し，社会及び経済を改善・発展することが可能である。劇的な変化と経済成長を伴うそのような進歩は，結果として地球上での急速な資源消費をもたらした。しかしながら，社会経済プロセスへの資源需要増大は，資源搾取，廃棄物の増加，及び自然への排出を通じて自然環境の悪化に重大な責任を有する。

現在，各国が環境を保全する一方経済成長を促進する大きな挑戦に直面している。とりわけ経済的に劇的な過渡にいるアジア太平洋地域は世界の物質利用に大きく影響を与えるようになり，本地域や特定の国々における社会経済に関わる物質代謝及び物質フローの学術研究が拡大することとなった。しかしながら，多くの国々は世界のある地域として調査されているに過ぎず，資源需要と経済成長のパターンを読み解くキーとなり得るであろう各国固有の事象を不透明としている。本研究では，上述したギャップを埋めて，フィリピンにおける経済発展と環境政策を駆動する物質フロー・ストックの詳細な調査研究を通じて産業エコロジー研究の分野における知見へ貢献することを目的とする。また，アジア太平洋地域における中堅の新興経済及び次のステップへの社会動態の変遷に関するケーススタディとして位置づ

decoupling of economic growth and environmental pressure, and material efficiency in the country.

The first chapter of the thesis that results from the research project introduces the background, motivation, research objectives and presents the main research question "What are the trends of socio-economic metabolism in the Philippines?" Furthermore, the scope and limitations and structure of the dissertation is provided in this chapter. In essence, the aim has been to develop a knowledgebase that helps policy makers to address the dual objective of human development and environmental and resource conservation through resource efficiency and natural resource management policies. The timeliness of this approach has been reinforced by the recently agreed Sustainable Development Goals which address similar issues and require data and indicators that this study has produced.

The second chapter compiles the principles and theories, framework and refers to seminal studies employing economy wide material flow accounting and analysis. It discusses the system boundaries, and the relationship of the physical economy and the natural environment. It also introduces the Philippines, its socio-economic profile, and national environmental and developmental policies.

The third chapter presents the methodology to develop the material flow database of the Philippines which covers the period from 1980 to 2014. It highlights methodological improvements of the accounting tailored to the economic and metabolic characteristics of an Asian developing country. It thereby extends the Eurostat methods guidelines. Data

けた。本研究は，フィリピンの物質フロー勘定を構築することで，経済成長と環境影響のデカップリングに関して，傾向を捉え，要因を明らかにし，一国の資源効率を論じる。

1章では，研究の背景，動機，及び目的を示し，本研究の主題である「フィリピンにおける社会経済に関する物質代謝を傾向づけるものは何か」について述べた後に，本研究の全体構成を示す。本質的には，政策決定者が資源効率及び資源管理政策を通じて相反する人間活動と環境保全を両立する目的を達する役に立つ基盤となる知見を提示することが目的である。近年合意されているSDGｓに関して主要な議題及び指標群を提示することで，本研究を補強する。

2章では，原則と理論，枠組みをまとめて，エコノミーワイド物質フロー勘定及び分析を用いた精緻な研究手法を整理する。システムの境界および経済そのものと自然環境の関係について議論する。フィリピンにおける社会経済的側面及び国家の環境・開発政策を紹介する。

第3章では，1980年から2014年までのフィリピンにおける物質フローデータベースを構築するための方法論を示す。アジアにおける途上国の経済および代謝に関する特徴に合わせた勘定の方法論について改善を提案する。これによりEurostatにおける勘定手法ガイドラインを拡張する。本章では，データベースから得

sources, estimations, and indicators derived from the database are also discussed in this chapter.

The fourth chapter shows the trends of material flows and stock of the Philippines. It shows that during two decades the input, production and consumption of resources has doubled in the Philippines, and the country shifted from net resource dependence in 1980 to a net resource provider in 2014. The domestic extraction is further elucidated at the provincial level. Furthermore, this chapter provides the output indicator by showing the trends of material outflows to three environmental gateways – atmosphere, water and land. The waste and emissions released to the environment have tripled from 1980 to 2014. Net addition to stock grew slower than waste and emissions that is testament of a lack of infrastructure investment in the Philippines.

The fifth chapter presents the analysis of socio-economic metabolism of the Philippines. It finds that the country has transitioned from a biomass or renewable based to nonrenewable-based socio-economic system that has become dependent on large amounts of non-renewable materials creating new environmental problems. The research finds that population growth was the primary driver of material consumption but has been overtaken by affluence since the year 2000. Relative changes in resource use expressed as production indicator, Domestic Material Consumption (DMC) and consumption indicator, Material Footprint (MF) grew in unison but at a lower rate than GDP. This means a relative decoupling of material consumption and economic growth in the Philippines has been achieved. The Philippine economy grew while reducing the material intensity of the economy because of

られたデータソース，推計，及び指標についても述べる。

第4章では，フィリピンの物質フローとストックの動向を示す。フィリピンでは20年間で資源の投入，生産，及び消費が倍増し，1980年の純資源依存から2014年の純資源供給に移行したことが示されている。国内ではとりわけ州レベルでさらに詳細が示されている。さらに，3つの環境ゲートウェイ（大気，水，土地）への物質フローの傾向を示すことにより，アウトプットの指標群を示す。環境に放出された廃棄及び排出は，1980年から2014年にかけて3倍に増加した。蓄積純増はフィリピンにおけるインフラ投資不足の影響により廃棄や排出と比較して鈍化したことが示された。

第5章では，フィリピンの社会経済に関する物質代謝分析を示す。国が新しい環境問題をもたらす大量の再生不可能な物質に依存してきた結果であり，バイオマス及び再生可能な資源から再生不可能な社会経済システムに移行したことに起因する。人口増加が主要消費者の原動力であったが，2000年以来の豊かさにより追い抜かれたことが明らかとなった。資源生産性，国内資源消費（DMC）、消費に関する指標、マテリアルフットプリント（MF）がGDPと異なる傾向が示された。フィリピンの資源消費と経済成長の相対的なデカップリングが達成されたことを意味する。フィリピン経済は，

the increasing share of GDP occurring in the relatively less material intensive services sector. In the same vein, the output to the environment, indicated by Domestic Processed Output (DPO) grew at a lower rate than GDP from the year 2005. This relative decoupling does not mean an overall reduction of DPO since the environmental Kuznets curve shows growing pressure on the environment as the economy grows.

The sixth chapter presents the policy implications of the research project. It shows how this study responds to the information requirements of a modern environmental policy stance that looks at economy and environment simultaneously. This knowledge base has not previously been available in the Philippines. The study findings call for strengthened policies on resource efficiency, waste minimization and greenhouse gas abatement. The dataset also shows slow progress in achieving Sustainable Development Goal (SDG) targets 8.4, 12.2 and 12.5.

The seventh chapter concludes this study. It provides details of achievements based on the objectives. The limitations and the areas for future studies are also presented in this chapter.

The core of this research has been published in three peer-reviewed journal publications in high-level journals including Journal of Industrial Ecology, Ecological Economics and Resource Conservation and Recycling. Beyond the contribution to the scholarly literature and knowledgebase for the science of industrial ecology the study has also presented a data set and indicators that is relevant to public policy in the Philippines and in other ASEAN economies.

相対的に資材の少ないサービス部門においてGDPのシェアが増加していることから，経済に関する資源強度低下を伴い増加したことが示された。同じく，DPOが示すGDP比は，2005年からGDP比で低下した。相対的なデカップリングは，環境クズネッツ曲線の影響が色濃くなることからDPOの全体的な削減とは異なり経済成長に伴って環境に影響を与えた。

第6章では，本研究の政策的含意を示す。経済と環境を両立する現代の環境政策が必要とする状況がどのように対応するかを明らかにした。明らかとなった知見は，以前フィリピンでは利用不可能であり，本成果は，資源効率，廃棄物の最小化，温室効果ガス削減に関する政策を提言する。データより，持続可能な開発目標目標（SDG）の8.4，12.2および12.5を達成することにわずかながら進展が示された。

第7章では本研究の結論を示した。また，今後の研究に関して課題及び改善点を示した。

本研究内容はJournal of Industrial Ecology，Ecological Economics及びResource Conservation and Recyclingの3つの査読ジャーナル誌に掲載された。本研究は産業エコロジー分野における学術文献や知識基盤への貢献だけでなく、フィリピンや他のASEAN諸国経済の公共政策に関連するデータセットと指標も提示した。

Table of Contents

1. Introduction

1.1 Background

The demographic and economic growths and technological advances on the onset of the 20th century resulted in unprecedented growth in global material extraction. Recognizing the finite, limited supply and unequal distribution of natural resources, its overexploitation has been identified as a major global environmental problem (UNEP 2011b; Giljum et al. 2010). Most growth in material use has occurred in the Asia-Pacific region, the most populous and economically dynamic world region, which surpassed the rest of the world in terms of material use in 2008 (Schandl and West 2010) and has now become the largest user of biomass, fossil fuels, metal ores and non-metallic minerals (UNEP 2013a; UNEP 2016). Figure 1 depicts the trends of world's domestic material consumption by showing the contributions of seven sub-regions. The growth patterns in this region affect the global demand and consumption of materials and subsequently affect not only the regional environment but also the entire global environment.

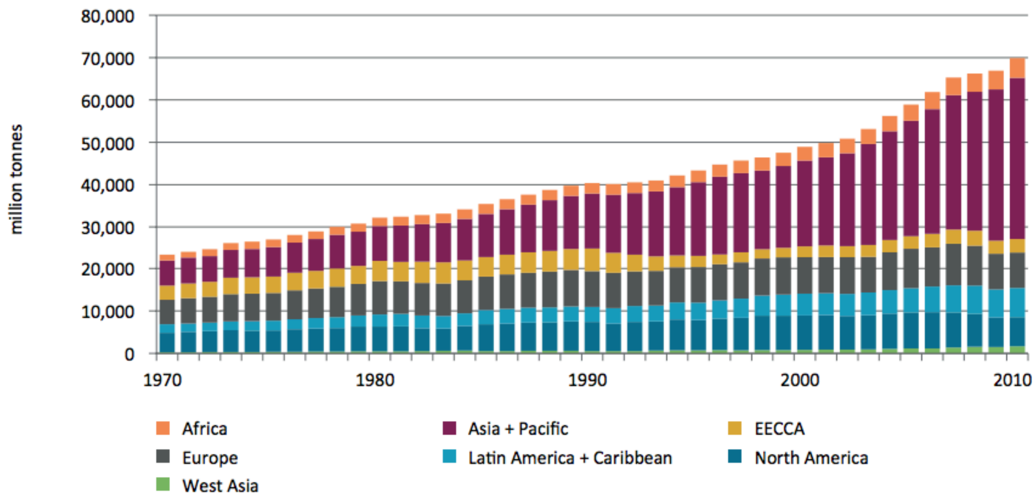


Figure 1. The world and regional domestic material consumption.
Source: UNEP 2016

Decoupling the economic prosperity with resource consumption and eventually to the environmental impacts has been the core mandate of the International Research Panel and the Green Economy Initiative of UNEP. It argues that achieving a sustainable economy calls for decrease in the use of resources while expanding the economy thereby reducing impact to the environment, thus ensuring the well-being of the people. Decoupling can be described as resource decoupling that occurs when resource use increases slowly than the economic growth; and impact decoupling that occurs when environmental impact decreases while the economic growth increases (UNEP 2011), as shown in Figure 2. Resource decoupling can be further described as absolute or relative. Absolute decoupling occurs when the resource consumption is declining in absolute terms, for instance, the economic growth is increasing while the resource use is in decline. On the other hand, relative decoupling occurs when resource use is increasing at a lower rate than the economic growth or economic output (Jackson 2009). Despite of contentiousness on the plausibility of decoupling of economic growth and environmental impacts in the developed nations, the efforts towards resource efficiency, reduction in material throughput and harnessing renewable energy are acknowledged to be a vital role towards sustainable economy (UNEP 2011; Jackson 2009).

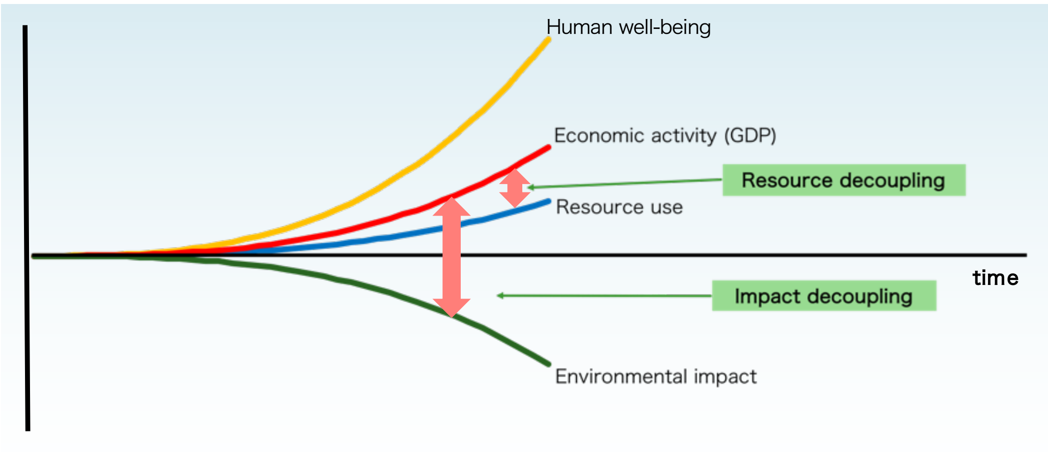


Figure 2. Resource and impact decoupling.
Reference: UNEP 2011

With the recognition alarming trend of unprecedented growth of material resource consumption accompanying economic growth, the 22 Asian countries pledged through a non-binding declaration called the Manila Declaration on Green Industry in Asia 2009 to improve resource efficiency, integrate sustainable consumption and production, and de-link economic growth from environmental degradation – aiming for the continuous growth of economies while at the same time reducing impacts to the environment (UNIDO 2009). Further, the new policy objectives of decoupling and decarbonization require robust information to guide policy formulation and to monitor and evaluate policy effectiveness. Indicators of material use that are complementary to the System of National Accounts (SNA) have gained popularity in many Asian countries, such as China (UNEP 2011a) and Japan (Moriguchi 2006; Hotta 2011), wishing to pursue a policy agenda which integrates economic and environmental objectives.

The evidence base for natural resource use and resource productivity in the emerging economies has grown and this has coincided with increasing interest in the policy community in a better understanding of natural resource accounts and indicators for materials and waste, energy and emissions, and water use. Interest in national material flow accounts has been reinforced by the newly adopted Sustainable Development Goals (SDGs) which aim to achieve economic growth, human wellbeing and environmental integrity simultaneously. Achieving all SDG objectives will require a massive effort to decouple economic growth from environmental pressure and impacts. Specifically, SDG target 8.4 aims to improve resource efficiency of production and consumption. In a similar vein, SDG target 12.2 focuses on the sustainable use of natural resource. SDG target 12.5 for waste reduction is also relevant in this context and it is obvious that a smaller material throughput will also contribute to reduced waste and emissions.

The material resources available in the natural environment are transformed into various forms to support man's needs, provide convenience, and facilitate further growth of the society. How immense the material flow varies on the magnitude and level of economic growth. Because of its relevance and applicability, material flow analysis (MFA) has grown and expanded its scope outside the academia and research institutes. MFA provides indicators towards the assessment of intensity, efficiency and productivity of resource use of the society. These indicators served as tool to develop and evaluate policies on management of natural resources. MFA has also gained respect on its application on waste management and recycling systems. While national statistics compile sufficient data to account the material inflow, wastes statistics or outflow remains to be insufficient, and requires standardization for better comparison among nations (Moriguchi and Hashimoto 2016). Few studies have been done covering the accounts of outflows to the environment. Highly notable first efforts to account and compare domestic processed output among nations were done for Austria, Germany, Japan, Netherlands and United States (Matthews et al. 2000). Succeeding studies were conducted in European countries such as Czech Republic (Scasny et al. 2003) and Italy (Barbiero 2003). Recently, literatures are available for upper middle-income countries such as China (Dai and Wang 2017); as well as the capital cities such as Cape Town in South Africa (Hoekman and Von Blottnitz 2016). Studies including the accounts of output to environment have been deemed necessary to come up with the total assessment of resource management as well as evaluation of related polices.

The fact that the Asia-Pacific region has become so crucially important in global material use is reflected in the increased volume of scholarly studies of socio-economic metabolism and material flows for the region (Schandl and West 2010; Schaffartzik et al. 2014) and a growing number of policy reports (UNEP 2011b, 2013a, 2015). The UN Environment Asia and the Pacific Office has created a material flow dataset for all Asian developing economies based on internationally available data. Unsurprisingly, however, much attention in the global climate policy discourse and scholarly debate has focused on the "Growing Giants", i.e. the BRICS countries and especially China and India (Hubacek et al. 2007; Tian and Whalley 2010; UNEP 2011a) due to the sheer size and dynamic growth of their populations, economies, and environmental pressures as well as the global repercussions of the material requirements of their economies. This means that other emerging markets have received less consideration, even if data has become available. Many countries have only been examined as constituents of global regions, obscuring country-specific details, which may be key to understanding patterns. This fallacy may prove to be considerable: while relatively smaller than India or China, other emerging market countries are still among the most highly populated in the world; they cover large geographical areas and are often hotspots of climate impacts and biological diversity. Their accumulated economic activity and environmental impacts rival other global regions and are dramatically rising

(UN DESAPD 2015; IMF 2015; Mittermeier et al. 2011). In other words, while there is only one China and one India, there are many developing countries that share comparable socio-economic growth paths. Knowledge obtained about one could very well be of substantial relevance to understanding general patterns of the material needs of economic development. Moreover, few studies have focused so far on the other newly emerging economies in South and South-East Asia. While studies of the Asia-Pacific region (Schandl and West 2010; UNEP 2011a) provided per-country data using international data sources, analysis was conducted only on the sub-regional scale and on a selected number of countries, of which the Philippines was not one.

Whether on the global, regional, or national scales, the framework of actions and policies towards sustainable consumption and production requires information on the trends of material resource extraction and consumption. In this context, the Philippines as a newly industrialized country and one of the most dynamic economies in South East Asia region (IMF 2012; World bank 2014) is worth investigating. The Philippines represents a high-density developing country (Krausmann et al., 2008), its population reached 101.9 million (M) in 2015 with a compounding annual population growth rate of 1.72% and average population density of 337 people per square kilometer in 2015 (World Bank 2017).

This study aims to fill this gap by an in-depth examination of the domestic material consumption and trade of materials mobilized by economic development and policy in the Philippines, which can serve as a case study for the socio-metabolic transition of a medium-sized emerging economy in the Asia-Pacific region and perhaps beyond. Furthermore, this study adds to the body of knowledge with the Philippines as an archipelagic country at an early stage of economic development. Thus, the results and analysis, as well as accounting factors may be beneficial for formulation of environmental and economic policies in similar geographical characteristics and development stages across the world. This study is part of a bigger research project in the Philippines that aims to provide thorough understanding on the environmental and economic challenges faced by the country through the framework of material flow and stock accounting.

1.2 Research motivation

The concept of material flow analysis is completely new to me when I started the graduate studies. I was introduced to this topic through a brief explanation simulating the body's metabolism to society's material input and output. It created a spark of deeper interest in me towards this research theme. Browsing further through scientific journal papers, methodological guidelines and few books written about the concepts of industrial ecology gave understanding of the basics of MFA. As a government employee on foreign scholarship grant, it is essential to learn something new and acquire the necessary skills that could contribute to the betterment of the Philippines in general. Reading further through the reports of UNEP and International Research Panel, I became more motivated to realize the policy implications of this research theme.

The national statistics of the Philippines has evolved when it comes to collection and access to data. The general public's access to the data has improved as well, with the data available in official websites; it cuts the need for time and bureaucracy. The statistical data for extraction, production, import and export of materials are reported separately and viewed independently. There is a need to put these data together and utilize these as to gain new, broader and deeper perspectives. The material flow accounting approach puts these data together and allows assessment and provides important perspectives on the relationship between society, economy and environment. With the expansion of statistical database, MFA can be further replicated and analyzed in different spatial levels in the country, which I believe is important and timely, given the differences in resource endowment, level of economic activities of the 81 provinces that is comprised of 7,107 islands of the Philippines.

A recent effort to utilize the EW-MFA framework was done to assess economy-wide material flow accounts and their implications in Myanmar, Bangladesh, and the Philippines (Maung et al. 2014). Comparing the totals of all material inflows, it revealed that the increasing resource extraction and consumption trends are influenced by the resource management policies and development patterns of these three countries. That study, however, presented only an approximation of the total aggregated material flows in a limited context of the Philippines. Specifically, for the Philippines, Rapera (2005) examined the relationship of material flows and poverty in the country showing a slight positive effect of biomass flows in poverty alleviation from 1981 to 2000 (Chiu (2011) discussed material flow accounts from 2000 to 2009 regarding the potential for green economy and sustainable consumption and production in the Philippines. However, these studies show disparities on the values of material flow indicators. Using primarily domestic data sources, this research aims to overcome these discrepancies and provide more precise long-term material flow accounts for the Philippines. With a dynamic yet volatile economic growth in the Philippines and the recent developments in the methods of Economy-wide Material Flow Accounts, it is a timely to compile a longer period of material flow accounts of the Philippines in a disaggregated, per material category basis as presented in this study.

This PhD research hopes to introduce the MFA to the Philippines and vice versa, starting from developing a full economy-wide material flow accounts from the national statistics data to providing analysis of MFA at different perspectives. The ultimate goal is for this piece of work to move its way towards policy formulation, evaluation and assessment in the province of Palawan, and the rest of the Philippines.

1.3 Research objectives

1.3.1 Research questions

While previous MFA and socio-economic metabolism studies for the Philippines and the Asia-Pacific region examined material consumption from a generalized perspective and on macro scales, this research is based on five fundamental questions about the relationship of socio-economic and environmental systems specific to the Philippines:

1. How do then interactions between nature and society have changed over time through the extraction, consumption of materials, and emission of wastes?
2. What is the contribution of different regions and provinces in the domestic extraction of the Philippines?
3. What are drivers of material consumption in the Philippines?

4. Has decoupling occurred in the Philippines in terms of

    a. economic growth and material use?

    b. economic growth and output to environment?

5. How do changes in economic structure and development policies of the Philippines affects the socio-economic metabolism?

1.3.2 Objectives

Generally, this study is focus on the socio-economic metabolism of the Philippines thereby adapting and localizing methods of material flow accounting in the context developing nations in Southeast Asia.

Specifically, this research aims to:

1. Develop the full economy-wide material flow account of the Philippines
2. Elucidate the domestic extraction per province in the Philippines
3. Identify the drivers of changes in material consumption
4. Monitor progress of decoupling of economic growth, material use and environmental pressures
5. Understand this interrelationship in terms of the development policies of the Philippines and its effect on the ongoing socio-metabolic transition.

1.4 Scope and limitations

This research covers the direct material flow, or the materials that are extracted from domestic environment of Philippines and material imports from the rest of the world that are utilized in domestic socio-economic system. Unused materials accompanying extraction or harvest of raw materials, from domestic environment and from the rest of the world are not included in this account. These materials are called hidden flows or ecological rucksacks include the mining overburden or soil excavation during construction, flaring of gas in the oil and gas extraction. This study covers 34-year period, from 1980 to 2014.

While the data to account material inputs are readily available from the national statistics, the main limitation of this research is the availability of the data for the estimation of output to the environment. The actual generated solid wastes for instance is not reported in the national statistics; air emissions and wastewater discharge are reported in terms of concentration. Nevertheless, the estimations herewith are made based on the collected data and reports from various related government agencies, and data are gleaned using the methodological guide of Eurostat as a reference.

1.5 Research structure

Following this first chapter that introduces the background, motivation, research questions and objectives, scope and limitations, the rest of this dissertation is organized as follows:

The second chapter presents the principles and framework, related studies and it introduces the Philippines, its socio-economic profile, and national environmental and developmental policies.

The third chapter discusses the methodology and highlights improvements based on the Eurostat guidelines to develop the material flow database of the Philippines. It also shows data sources, estimations, and indicators derived from the database are also discussed in this chapter.

The fourth chapter presents the trends of material flows and stock of the Philippines. It also elucidates the domestic extraction at the provincial level. Furthermore, this chapter provides the output indicator by showing the trends of material outflows to three environmental gateways – atmosphere, water and land.

The fifth chapter discusses the analyses of socio-economic metabolism of the Philippines such as trends and changes, driving factors, the difference in production and consumption indicators, and monitoring decoupling of economic growth, resource use and environmental impacts.

The sixth chapter presents the policy implications of the research project. It shows how this study responds to the information requirements of a modern environmental policy stance that looks at economy and environment simultaneously.

Finally, the seventh chapter concludes this study. It provides details of achievements based on the objectives. The limitations and the areas for future studies are also presented in this chapter.

2. Research Principles, Framework and Study Area

2.1 Principles and theories

2.1.1 The principles of Industrial Ecology and Socio-economic Metabolism

The notion or concept of industrial ecology is based on how the natural ecosystem operates, where the input of one process is from the wastes, or output of another process. It also highlights the interaction of the natural ecosystem and the man-made ecosystem and attempts to promote cyclical flow and eventually move forward to closed loop system. Industrial ecology has a very broad area and has no standard definitions (Erkman 2001). White (1994) defined industrial ecology as "the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flow, use and transformation of resources." To describe further the processes within the scope of industrial ecology, the term industrial metabolism was proposed by Ayres (1989) to demonstrate the throughput of material and energy in the industrial systems. It utilizes the material flow accounting approach that compiles the physical units of these materials (in tons) thereby quantifying the inputs and outputs along those processes. Material flow accounting (MFA) is one of the tools of Industrial ecology, among others but not limited to the following; Substance Flow Analysis (SFA), Life Cycle Design and Assessment (LCDA), and Environmental Input-Output Analysis to evaluate the linkages of economic and environmental impacts (Bringezu and Moriguchi 2002).

To specifically describe the flows of materials and energy from nature to society, between different societies and within societies, terms such as societal metabolism (Fisher-Kowalski and Haberl 1993) and socio-economic metabolism (Fischer-Kowalski and Hüttler 1998; Fischer-Kowalski 1998) were coined. Socio-economic metabolism differs from industrial metabolism as it covers the flow of materials and energy in the industrial and nonindustrial sectors. The throughput of materials and the accompanying process such as extraction or harvest, conversion of materials to usable forms, consumption, recycling and disposal from natural environmental system to socio-economic system is analyzed through the material flow analysis

(MFA). Thus, MFA looks into the bulk of material flows, as this relates to socio-economic systems, while SFA looks into specific substances.

The attempts to simulate interaction between socioeconomic and natural system can be viewed at different levels: reference system such as global, national, regional, functional and temporal; flows under consideration such as energy, materials and substances; and time horizon, either dealing with contemporary point in time, time series, and long-range historical perspective (Fisher-Kowalski and Hutter 1998).

2.1.2 Economy-Wide Material Flow Accounts and Analysis

The law of conservation of matter states that matter is neither created nor destroyed in the course of its physical transformation such as the conversion of raw material into another product and its consumption; matter is just transformed into other forms, state or compounds. Also called as material balance, this principle serves as the logical basis for framing the physical economy through establishing the relationship of economy and environment in terms of exchange of materials.

The physical exchange of materials between national economies with the environment is quantified thru material flow accounts. The schematic presentation of EW-MFA is shown in Figure 3. The flow of materials and energy highlights the fundamental relationships between environment and economy that evolve through time. Materials are taken from the natural environment, where these undergo transformation into usable forms in the socio-economic system. Since the domestic environment cannot adequately supply the material requirements of the socio-economic system, materials must be imported from other socio-economic system or from the rest of the world. Materials within the socio-economic system has three fates; first these are released back to the environment as wastes generated when it undergo processing, utilizing and when it is no longer consumed in the society; second, as export or as materials that are supplied to the rest of the world; and third, materials used for physical infrastructures, transportation and other remain for a longer period in the society as stocks. The fundamentals of material input and output are captured in the economy-wide material flow accounts and analysis. The methodology of Economy-wide Material Flow Accounting/Analysis

(EW-MFA) is a useful framework to determine the metabolic performance of economies (Eurostat 2001; Bringezu et al. 2003; Fisher-Kowalski et al. 2011).

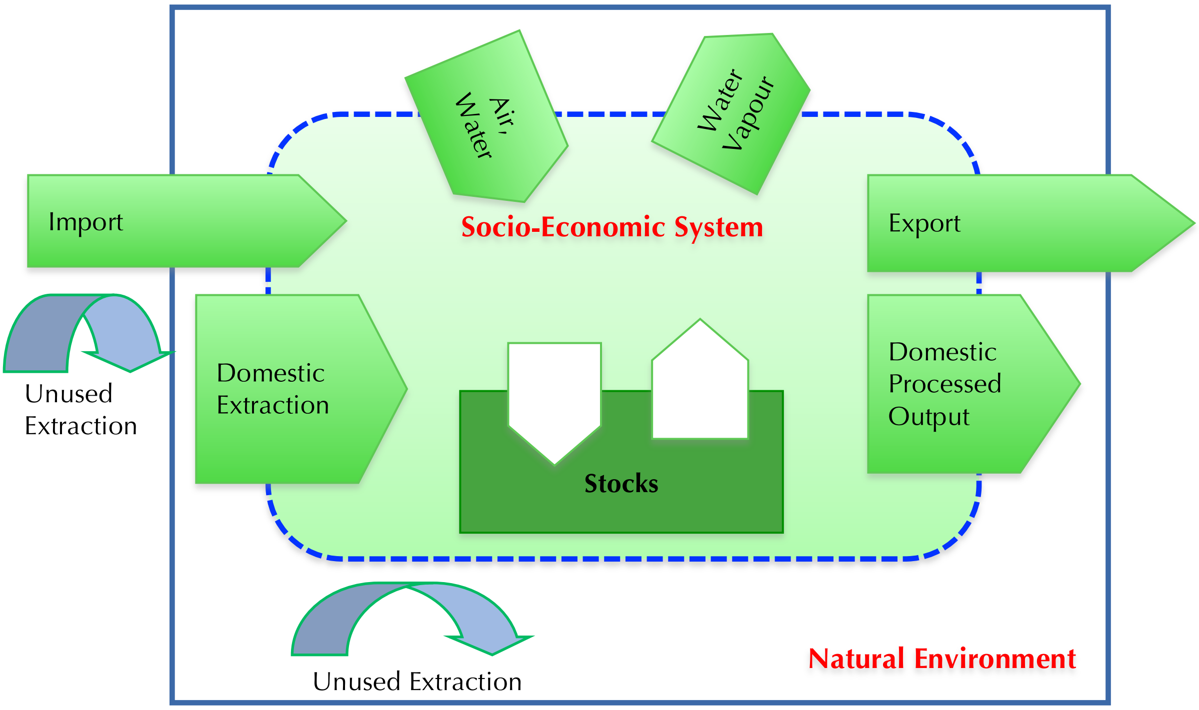


Figure 3. Schematic presentation of Economy-Wide Material Flow Accounts and Analysis.
Reference: Eurostat 2009; Matthews et al. 2000

The flow of material and energy create disturbances in the environment as materials are extracted and as wastes are generated out of the processing, consumption, and final disposal of products. As the material flows vary on the size and level of economic growth, it is regarded as an indirect indicator of pressure to the environment (Eurostat 2001; Matthews et al. 2000).

The aggregated flow of materials includes input flow namely domestic extraction and imports, and output flows such as domestic releases to the environment and exports, as shown in Table 1. Material flow account does not only focus on the resource extraction and consumption, but it also accounts resource disposal and recycling. MFA has gained respect on its application on waste management and recycling systems. Solid wastes are generated during extraction, production, transformation, and consumption of materials as well as the end of life of final products and its management has been one of the environmental challenges faced by developing nations.

Table 1. Economy-wide material balance with derived indicators.

Inputs (Origin)	Outputs (Destination)
Domestic extraction	Emissions and wastes
Fossil fuels (coal, oil, etc.)	Emission to air
Minerals (ores, gravel, etc)	Waste landfilled
Biomass (timber, cereals, etc.)	Emission to water
	Dissipative use of products
Imports	(fertilizer, manure, comport, seeds, etc.)
Direct material input (DMI)	*Domestic processed output to nature (DPO)*
Unused domestic extraction	Disposal of unused domestic extraction
From mining/quarrying	From mining/quarrying
From biomass harvest	From biomass harvest
Soil excavation	Soil excavation
Total material input (TMI)	*Total domestic output to nature (TDO)*
	Exports
	Total material output (TMO)
	Net addition of stock (NAS)
	Infrastructures and buildings
Upstream flows associated with imports	Other (machinery, durable goods etc.)
Total material requirements (TMR)	Upstream flows associated with exports

Source: Ayres and Ayres 2001

Following pioneering studies of the material flows of industrialized countries (Adriaanse et al. 1997; Matthews et al. 2000), EW-MFA has been standardized (Eurostat 2001; 2009; 2013) and enables a systemized accounting of the material inputs and outputs of local, national, or regional economies. Early applications of economy-wide MFA were to analyze expansion of physical economy such as in Austria in 1990 (Steurer 1992), Japan (Ministry of Environment 1992) and Germany (Schutz and Bringezu 1993). EW-MFA accounts have been proliferating in recent years for both developed countries (e.g. Krausmann et al. 2011; Gierlinger and Krausmann 2012; Schandl and West 2012) as well as for economies in different stages of development, such as Latin American countries (Giljum 2004; West and Schandl 2013; Manrique et al. 2013), countries of the former Soviet Union (West et al. 2014), and Asia and the Pacific (Schandl and West 2010). Much attention given to big countries with fast growing economies such as China and India (Hubacek et al. 2007; Wang et al. 2012; Giljum et al. 2010; Singh 2012).

It also gained attention and expanded thereafter covering various spatial and temporal scales. Studies have been undertaken in developed countries such as United States of America (Gierlinger and Krausmann 2012), Japan (Krausmann et al. 2011) and across longer study periods such as in Czechoslovakia (Kovanda and Hak 2011; Kuskova et al. 2008), United Kingdom (Schandl and Schulz 2002), and Spain 1860-2010 (Infante-Amate et al. 2015).

The materials remaining in the socio-economic systems as stocks are also an important indicator of the level of infrastructure development in a region or country, and the level of exchange of materials and energy from the environment had been regarded to be directly related to the growth of the economy (Wolman, 1965; Kennedy et al. 2007). The widely used methods to determine the material accumulation or stocks in the socio-economic system are either by statistical, use of geographical information systems (GIS) and remote sensing or a combination of two or all of these methods. Muller (2006) used the statistical data and survey information to determine the relationship of material stock and flows on the economic development in Netherlands and projected the future waste generations. Similar studies were done in Japan (Hashimoto 2009) and China (Hu et al. 2010), while Tanikawa et al. (2009) utilized the method of GIS to estimate the material stock and flows in cities of Manchester in England and Wakayama City in Japan. Long term accounts of economy-wide material stock accounts of 47 prefectures in Japan highlights the importance of material stock accounting in the study of socio-economic metabolism (Tanikawa et al. 2015). Kraussman et al. (2017) opined that the global socioeconomic material stocks are likely to grow despite of the recycling efforts, being driven by infrastructure development in emerging countries.

Studies accounting the waste flow and material stocks are likewise progressing but are being challenged by insufficient data on outflow and wastes statistics (Moriguchi and Hashimoto 2016). Foremost studies were conducted that utilized MFA to quantify wastes from construction and demolition wastes in Japan

(Hashimoto et al. 2007; 2009), China (Shi et al. 2012), Taiwan (Hsiao et al. 2002); for sustainable materials management (Pi-Cheng et al. 2017); as tool to improve waste management system in Austria (Allesch and Brunner 2016); and to quantify wastes or the "lost material stock" brought about by great east Japan earthquake (Tanikawa et al. 2014).

2.2 MFA and Sustainable Development Goals

The uneven distribution and ultimately finite supply of natural resources have been identified as important limiting factors for human wellbeing and economic prosperity (Behrens et al. 2007; Giljum et al. 2010). The intensifying rate of extraction in many places to meet burgeoning demand, resulting in overexploitation of the natural resource base in many countries, has been identified as a major global environmental problem (Kovanda and Hak 2007).

The new Sustainable Development Goals of the United Nations (Griggs et al. 2013), the Paris climate mitigation agreements (United Nations 2015) and the resource efficiency initiative of the Group of 7 economies (UNEP 2016) all show renewed interest from the global policy community in reducing environmental pressures and impacts of economic growth to enable human development based on sustainable natural resource use and a decarbonized energy system. Harmonizing human development goals with environmental objectives and natural resource conservation, however, is a particular challenge for Asian developing countries and emerging markets that have a large backlog of infrastructure and human development needs.

The urgency for all nations to take action is highlighted in the Sustainable Development Goals (SDGs) released by the United Nations in August 2015, where one of the goals is to ensure the sustainable production and consumption patterns of nations. Sustainable consumption and production (SCP) calls for the efficient use of natural resources and for minimizing waste flows (UNEP 2015).

Decoupling economic growth, employment and social progress from pressures and impacts on the environment is the ultimate objective of SCP. While this concept is not a panacea for the current complex socio-economic and environmental issues, it is nevertheless a very important policy program and includes efforts to raise the eco-efficiency of industries, encourage green public procurement and responsible household consumption, and increase investment into green infrastructure. SCP suggests that economic growth can be achieved while reducing environmental pressures and impacts, through prioritizing cost-effective options for decoupling in housing, mobility, food and energy provision. In the long run, decoupling may well enable better social and economic outcomes compared to business as usual (UNEP 2017).

Understanding the material flows of the economy is a first step in addressing resource-related environmental issues towards sustainable development. Physical accounts of socio-economic growth provide the necessary detailed information of material consumption and allocation, and its relationship to economic growth. Through the years, MFA has grown and expanded its scope outside the academia and research institutes. Its indicators have been utilized as tool to develop and evaluate policies on management of natural resources. The established material flow accounts of Japan led to formulation of indicators and targets towards a sound material-cycle society (Ministry of Environment 2011). MFA analyses were conducted on productivity at global scale (Steinberger et al. 2013; Schandl et al. 2016); and regions of Asia-pacific (Schandl and West 2010), Latin America and Caribbean (West and Schandl 2013), and Soviet Union (West et al. 2014). Likewise, intensive studies were conducted on leading economies in Asia and Pacific such as China, South Korea and Japan (Dong et al. 2016); and China, Australia and Japan (Schandl and West 2012).

MFA provides indicators towards the assessment of intensity, efficiency and productivity of resource use of the society. These indicators help the nations to monitor trends towards achieving the Sustainable Development Goals (SDG). The consumption (material footprint) and production (domestic material consumption) indicators are used to monitor improvements on SDG targets 8.4 and 12.2. SDGs 8.4 calls for improvement of efficiency in resource consumption and production and decouple economic growth from environmental degradation while SDG 12.2

aims for a sustainable management and efficient use of natural resources. On the same vein, the demand for prevention, reduction, recycling of wastes stipulated in SDG 12.4 with recycling rate as an indicator. However, the nations' effective translation/implementation and capacity to implement SDGs vary as the level of economic development, national policies and priorities are different. The lack of studies and established data constraint is among of the challenges of its implementation in the many developing economies. As more nations identify themselves as active participants to attainment of SDGs, studies and researches should double its efforts to provide the timely and reliable data to support formulation of necessary policies.

2.3 THE PHILIPPINES

The Philippines is an archipelagic country that lies in the southeastern coast of Asia, and is bordered by the waters of Bashi Channel up to its north, Sulu and Celebes Seas down to its south, the Pacific Ocean to its east, and South China to its west.

It has 7,107 islands stretching to an area of 300,000- square kilometer or 29.8 M hectares. Luzon, Visayas and Mindanao are the three largest groups of islands. It is divided into 17 regions, with 81 provinces as shown in Figure 4. Lining the Philippines edges is the world's longest discontinuous coastline of 34,600 kilometers. Two distinct seasons, the wet (June until November) and the dry (December to May), characterize the climate of the country.

The country is extraordinarily diverse in terms of geography, ecology, natural resource endowments, economy, ethnicity and culture. It is the second-largest archipelagic state in the world, after Indonesia. There are estimated to be 110 ethnic groups and 170 spoken languages. Manila is the capital city and at center of economic activities in the country. The Philippines is also a member of Association of South East Asian Nations.

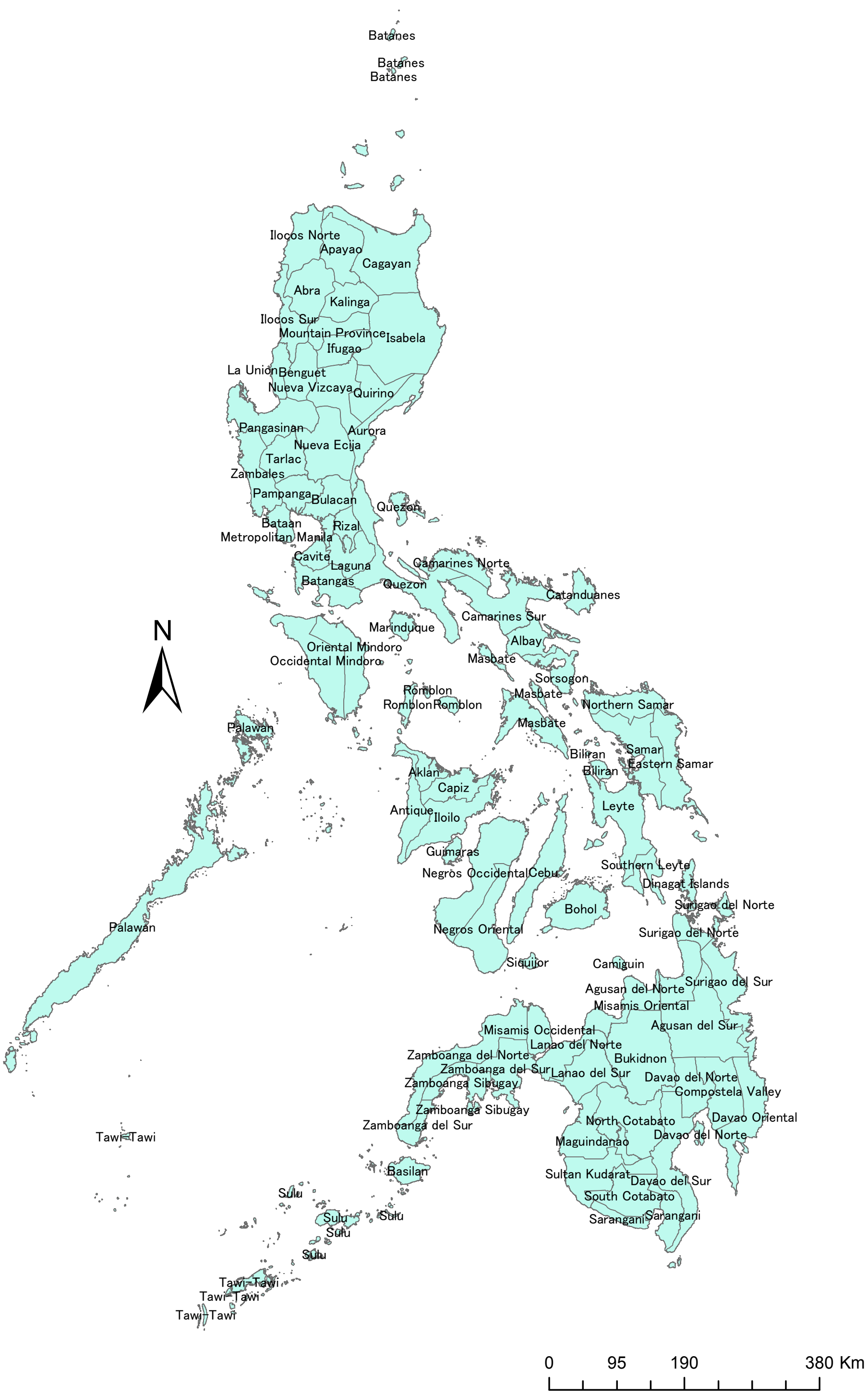


Figure 4. Map of the Philippines showing the geographical boundaries of the provinces.

2.3.1 The Socio-economic system of the Philippines

The Philippines is among of the prolific countries in the world. It is highly populated with 101.9 million (M) in 2015, population density of 337 per square kilometers, and an annual growth rate of 1.72% (2010-2015). The rapid population growth has been a challenged the economic development of the Philippines. Figure 5a shows the year-on-year trends in population and population growth in the country.

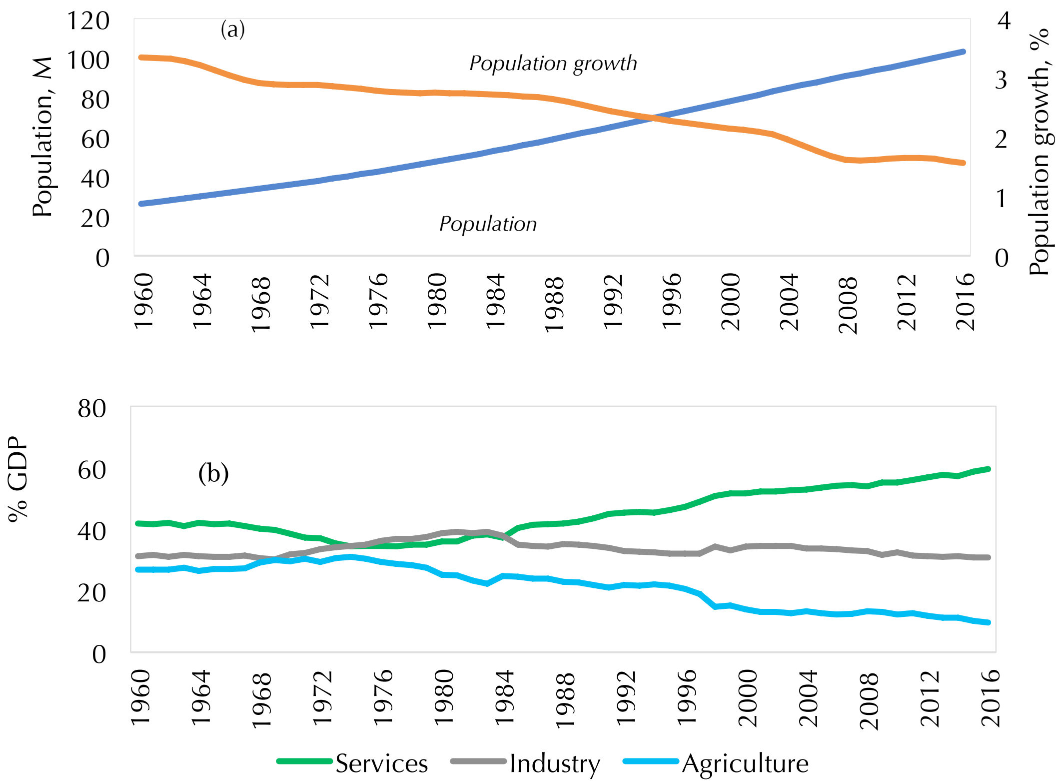


Figure 5. Share of economic sectors in GDP in the Philippines.
Reference: World Bank 2017

The Philippine economy has two important features setting it apart from its neighbors in the region. Firstly, the share of industry sector in GDP, at 31% in 2014, is lower than that of its ASEAN neighbors. Other major ASEAN economies have an industrial share of GDP of around 45% or more. Secondly, the Philippines have an exceptionally high share of household final consumption in GDP at 73% compared to Indonesia (57%) and China (37%) meaning that the Philippines have a low amount of capital investment, resulting in poorly maintained or lacking public infrastructure. The rest of the ASEAN region capitalizes on investment and net exports to generate the bulk of GDP. Furthermore, the Philippines take advantage of a steady flow of remittances from overseas workers, equivalent to 10% of GDP in 2014. This provides resilience for the Philippine economy against internal and external economic pressures (PSA 2015; World Bank 2016).

The Philippines economy has undergone stark structural change over the past two decades with agriculture declining in its contribution to GDP from 24% in 1980 to 11% in 2014 (Figure 5b). The industry sector's share declined from 37% to 31%, while services continuously expanded and its share grew from 36% to 58% of GDP between 1980 and 2014 (PSA 2015). It also increased its scope in providing employment to 54% of the workforce in the country in 2016, while the industry sector has stagnated in terms of providing jobs. Table 2 presents the changes in socio-economic indicators of the Philippines from 1980 to latest year available.

Table 2. Changes in the Philippines' key socio-economic indicators.

Indicators	Unit	1980	1990	2000	2010	2016
Population	million	47.4	61.9	78.0	93.7	103.3
Population density	people/sq.km	159	208	261	314	346
GDP	million US$	79,972	94,520	125,384	199,591	284,477
GDP/capita	US$ (2010 constant)	1,687	1,526	1,607	2,129	2,753
Agriculture	% of GDP	25	22	14	12	10
Industry	% of GDP	39	34	34	33	31
Services	% of GDP	36	44	52	55	59
Life Expectancy	years	62.2	65.3	67.2	68.4	69.0[2]
Literacy rate	%	-	-	92.6	95.4[3]	96.4[4]
Poverty ratio	%	28.1[5]	26.6[6]	14.5	10.7[7]	8.3[8]
Labor force	%	29.5	64.5	64.3	64.1	63.7[10]
Unemployment	%	4.75	8.13	11.19	7.35	6.29
Gini	ratio	41[11]	[12]43.8	42.8	[13]41.8	[14]40.1

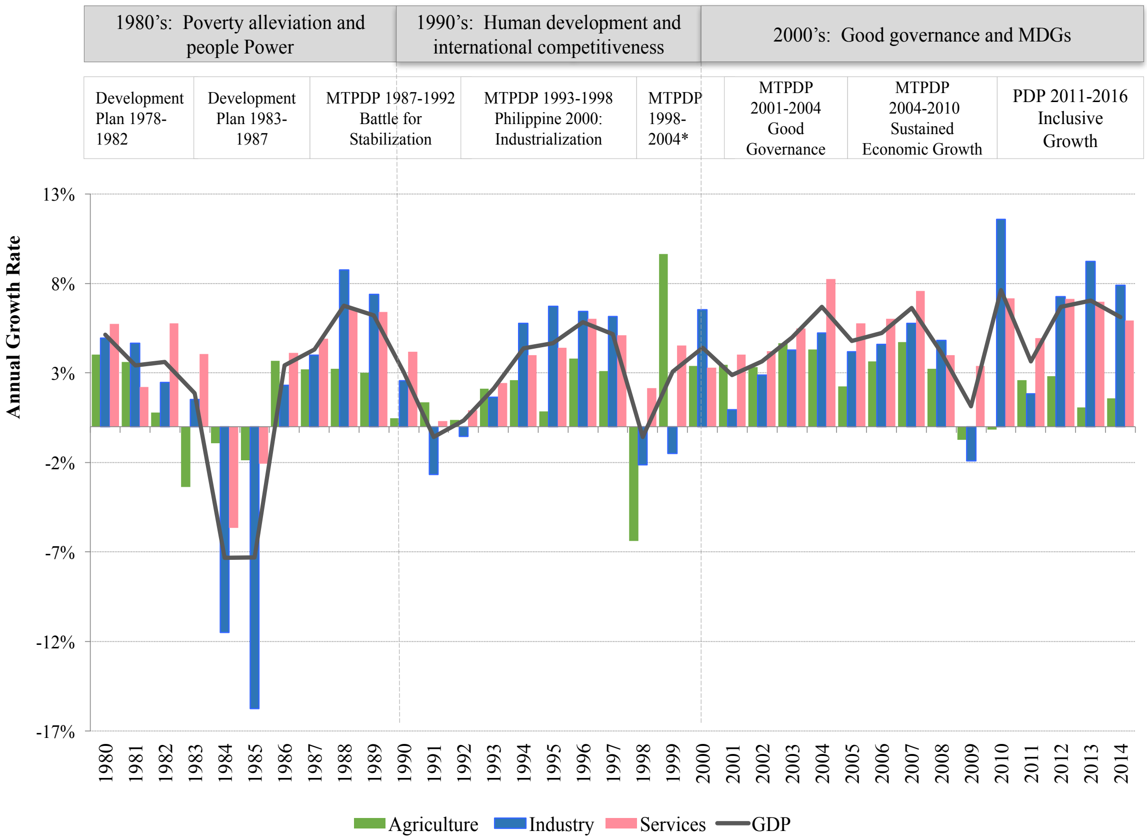
Sources: World Bank Indicators 2017 and Philippine Statistical Yearbooks, various years
[1]:1961; [2]:2015; [3]:2008; [4]:2013; [5]:1985; [6]:1991; [7]:2009; [8]:2015; [9]:1983; [10]:2015; [11]1985; [12]1991; [13]2009; 2015; GDP: US$ 2010 constant; Agriculture, Industry and Services: value added, % of GDP; Life expectancy at birth, total (years); Literacy rate adult total (% of people ages 15 and above); Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population); Labor force participation rate, total (% of total population ages 15+;national estimate) ;Unemployment, total (% of total labor force) (national estimate);Gini index (World Bank estimate).

During these three and a half decades GDP grew threefold from 80 billion US$ (1,687 US$ per capita) in 1980 to 284 billion US$ (2,753 US$ per capita) in 2016 (World Bank 2017). The economic growth from 1980 to 2014 shows that

GDP (in constant 2010 prices) increased by a cumulative growth rate of less than 2%, much slower than other high-growth Asian economies such as Viet Nam and China, which experienced double-digit GDP growth for a decade or more.

2.3.2 Development policies and economic transformation in the Philippines

The broad development agenda, goals and objectives are presented in the Medium Term Philippine Development Plan (MTPDP), which provides general policy direction and is the backbone of the government's economic strategy (Martin 2014). Despite its important role in national economic planning it lacks continuity because the planning focus tends to change every time a new administration or president is elected to office, resulting in a lack of economic and planning certainty. The 34-year period covered in this study encompassed eight national development plans (Figure 6).



**The President stepped down in 2001 brought about by people power revolution*

Figure 6. Philippine annual economic growth vis-a-vis development policies from 1980 to 2014.

The development vision in the 1980s was focused on poverty alleviation and was people centered; human development and international competitiveness dominated the policy agenda in the 1990s while good governance and rule of law was the main policy mantra in the 2000s (Jurado 2003). From 2004 the Millennium Development Goals were seen as the main reference point for public policy in the Philippines; they were mainstreamed into the MTPDP framework from 2004 to 2010.

1980s: Poverty alleviation and people-centered policies

Philippine policy elites considered economic growth during the 1970s to be unbalanced as it was largely fueled by a protectionist incentive structure, and relied on foreign debt-led growth to support public investment in infrastructure and energy. Despite this dependency, manufacturing activity had the highest growth rate, driven by exports of semi-conductors and garments as major manufactured exports. It had limited economic impact across the whole economy, though, due to the high share of imported inputs. The effects of the second oil price shock, a steep increase in world interest rates, and recession in industrialized countries were felt in the Philippines economy. All economic sectors were affected, with the industrial sector affected the most (–15.7%) and GDP contracted by 7.3% in 1984 and 1985 (Tecson et al. 1996; World Bank 2017).

To emerge from the political and economic turmoil, achieving economic stabilization was the main objective of the development plan of 1987. It focused on strengthening political and civil society institutions, included policies to cut tariffs, and aimed for trade liberalization in key commodity sectors. To promote foreign investment, a policy providing incentives to enterprises that exported at least 70% of their production or invested in areas identified in the investment priority plan was also implemented. The economy, however, was not resilient enough to stand another series of internal and external shocks brought about by the coup attempt in 1989 and the upsurge in oil prices.

1990s: Human development and international competitiveness

The 1990s started with negative GDP growth, and economic conditions worsened when the biggest volcanic eruption in a century occurred in the country in mid-1991 resulting in very large repair costs. A further liberalization of investment policy was enacted, allowing 100% foreign equity in many areas except for some strategic assets. The policy on Build-Operate-Transfer (BOT) was enacted in 1990; it aimed to fast track construction of infrastructure projects through contractual arrangements between private sector investors and the government. Deregulation of the oil and telecommunication industries was also put forward to address the power crisis. The Electric Power Crisis Act in 1993 encouraged the construction of new power plants through a private-initiative scheme.

The vision of becoming a newly industrialized country by 2000 was the guiding principle of MTPDP 1993–1998, focusing on human development, macro economy and development financing, agro-industrial development and infrastructure development (Martin 2014). A national law that provided a framework to promote housing programs and urban development in the country was enacted in 1992. The Philippine Mining Act (1995) was also put forward to revitalize the mining industry in the country by opening the sector to foreign investment.

The 1990s was a period of globalization characterized by an active construction industry and the emergence of a service-oriented economy, while the agriculture sector began to decline (Abrenica and Llanto 2003). The industry sector gained momentum from new policy settings and registered high annual growth rates. GDP also showed decent growth, but declined in 1998 when the Asian Financial Crisis hit the region. Furthermore, a severe El Niño hit the country during 1997–1998, resulting in –0.6% GDP growth in 1998. Agriculture was severely affected, registering a growth rate of –6.4% in the same year resulting in high food prices and putting food security at risk. To recover from the economic downturn, the development plans from 1998 focused on strengthening rural development, sustained infrastructure development, macroeconomic stability and global competitiveness along with reforming the governance system.

2000s: Good governance and the Millennium Development Goals

The vision of economic development remained at the center of MTPDP from 2001 to 2004, highlighting the need to eradicate poverty. Although GDP grew from 3% in 2001 to 6.7% in 2004, the unemployment rate also increased from 11.1% in 2001 to 11.8% in 2004 because of a fast-growing population, and the industry failed to absorb new entrants to the labor market (Aldaba 2014). Economic growth was mostly driven by extraordinary growth in remittances from foreign workers, reaching 13% of GDP in 2004 (World Bank 2016). In this period, environmental protection laws were strengthened through the enactment of national laws on solid waste and watershed management. In addition, policy to develop indigenous energy and promote foreign investment in the energy sector was enacted in 2001.

The MTPDP 2004–2010 continued the central goal of economic development and poverty reduction and setting national targets for Millennium Development Goals (MDGs) by 2015 (Briones et al. 2011). At the same time, national laws promoting biofuels, utilization of renewable energy, and Climate Change Act were established in 2006, 2008, and 2009 respectively. The national economy showed modest growth until it was halted again by the global financial crisis in 2008–2009 but has bounced back, reaching 7.6% annual growth in 2010.

The Philippine Development Plan (PDP) 2011–2016 is focused on ending the perennial problem of poverty, as well as strengthening public-private partnerships to enable infrastructure development and industrial activity. It proposes mitigating impacts of climate change through the National Green Program. The economy grew robustly at 7% in 2013, unperturbed by the slow recovery of major economies in the western hemisphere, as well as the ravaging super typhoon Haiyan that hit the country in the last quarter of the same year. The Philippines has emerged as one of the best performers among Asian economies in the current period (NEDA 2014), which can be attributed to good governance, sound spending and strong domestic consumption. How has the uneven and interrupted economic development in recent decades been reflected in natural resource use in the Philippines?

2.3.2 Environmental issues and policies in the Philippines

The knowledge base for the material consequences of economic growth in Asian economies (Schandl and West 2010) in general and the Philippines economy in particular (Martinico-Perez et al. 2017; Chiu et al. 2017; Martinico-Perez et al. 2018) and in comparison to other developing countries in Asia (Maung et al. 2015) has been growing in recent years. These studies focused on material flows and implemented the international guidelines for material flow accounts laid out by the European Statistical Office. They used international and domestic datasets to establish the accounts and indicators. Similarly, research into energy use and energy efficiency (Pacudan and de Guzman 2002; Silang et al. 2014; Kennedy et al. 2015; Cabalu et al. 2015; Quilty et al. 2015) and greenhouse gas emissions has also grown (World Bank 2016; EDGAR 2018; DOE 2012; UNDP and GOP 2011). Most analysis shows a policy focus on renewable energy, the share of which will increase in the Philippines' energy mix for power generation, however, fossil fuels, oil in particular, will remain the leading energy sources in the near future (Brahim 2014).

The evidence base for natural resource use and resource productivity in the emerging economy such as Philippines has grown and this has coincided with increasing interest in the policy community in a better understanding of natural resource accounts and indicators for materials and waste, energy and emissions, and water use. Interest in national material flow accounts has been reinforced by the newly adopted Sustainable Development Goals (SDGs) which aim to achieve economic growth, human wellbeing and environmental integrity simultaneously. Achieving all SDG objectives will require a massive effort to decouple economic growth from environmental pressure and impacts. Specifically, SDG target 8.4 aims to improve resource efficiency of production and consumption. In a similar vein, SDG target 12.2 focuses on the sustainable use of natural resource. SDG target 12.5 for waste reduction is also relevant in this context and it is obvious that a smaller material throughput will also contribute to reduced waste and emissions.

Awareness among the national policy elites in the Philippines is high and has resulted in a number of cross-cutting environmental policies that support efforts towards green growth, sustainable consumption and production and energy efficiency (Appendix 4). Sustainable development is a primary focus for the development of the agriculture and fisheries sector laid out in the Agriculture and Fisheries Modernization Act of 1997. Similarly, the Clean Air Act of 1999 requires compliance by industries and companies to reverse air pollution through both regulatory and market-based instruments; the Ecological Solid Waste Management Act of 2000 calls for proper transfer, transport, processing, and disposal of solid wastes; the Philippine Clean Water Act of 2004 aims for protection of all water bodies from land-based sources of pollution to be achieved through comprehensive water quality management. More recently, policies furthering cleaner production and energy efficiency have been put forward in the Biofuels Act of 2006 and the Renewable Energy Act of 2008. The Climate Change Act was also enacted in 2009 to coordinate, monitor and evaluate programs to curb the impacts of climate change in the country.

The Philippines has commendable environmental policy and legal frameworks in place providing a foundation to switch from the current unsustainable patterns of consumption and production to sustainable development of the Philippines economy and society. Policy implementation, however, remains a challenge with environmental and socio-economic indicators for the Philippines suggest a considerable gap between the rhetoric of the lawmakers and actual sustainability, outcomes (Sta. Romana 2017). A national strategy and objectives for the Philippines can be modeled after the successful high-level policy initiative of Japan for a Sound Material Cycle Society (Takiguchi and Takemoto 2008).

How does MFA can help in the environmental, social and economic issues in the Philippines? Table 3 shows why material flow and stock accounts are important in the Philippines. The indicators can be utilized as a proxy to gather historical evidence based and monitor changes and progress on certain improvements brought about by dynamics in economic policies that drives changes in the socio-economic and environmental system of the Philippines.

Table 3. Why MF/S analysis is needed in the Philippines?

Issues	How does MFA help? Past, present, future	Indicators
1. Utilization of resources	• Provide insights into the structure and change over time of the physical metabolism of Philippines; • Derive a set of aggregated/disaggregated indicators for resource use; • Indicators for resource productivity and eco-efficiency by relating aggregate resource use indicators to GDP and other economic and social indicators; • Retroactive analysis and modeling of material extraction and consumption	• Domestic Extraction (DE) • Domestic Material Consumption (DMC) • DE/DMC vis-à-vis socio-economic growth • Resource Intensity DMC/GDP and DMI/GDP • Resource productivity GDP/DMC and GDP/DMI • Trade (import& Export)
2. Land Use/Biodiversity/ wildlife	• Quantifying extraction of natural resources and its consequent pressure to natural ecosystem	• Domestic Extraction (DE) • Carrying capacity (DE/ha) • DE/GDP
3. Pollution (Water, Air and Land) and waste potential	• Trends/quantity of air emission, discharge of wastewater and solid wastes disposal • Material consumption and stock	• Domestic Processed Output (DPO) • DMC • NAS
4. Urbanization, traffic, sprawl	• Materials accumulation in the construction, building of infrastructures. • Services from material stocks	• Material intensity • Material Stock • Net Addition to Stock (NAS)
5. Population Growth/Poverty/ Inequalities	• Determine the material intensity of lifestyles, by relating aggregate resource use indicators to population size and other demographic indicators	• DMC/Capita • DMC/GDP • GDP/DMC • Driving factors

3. Methodology: Developing the Material Flow Accounts

This section presents the methods of developing the full economy-wide material flow accounts. The succeeding calculations for the analyses of material flow are also discuss herewith. Figure 7 summarizes the process to develop the material flow accounts. The process is divided into three segments, namely: material input, consumption and net addition to stock, and material output. The data or estimations required are shown in elliptical shapes, interim or components of the indicators are shown in rectangular units, while the database for derived indicators are shown in cylindrical shapes.

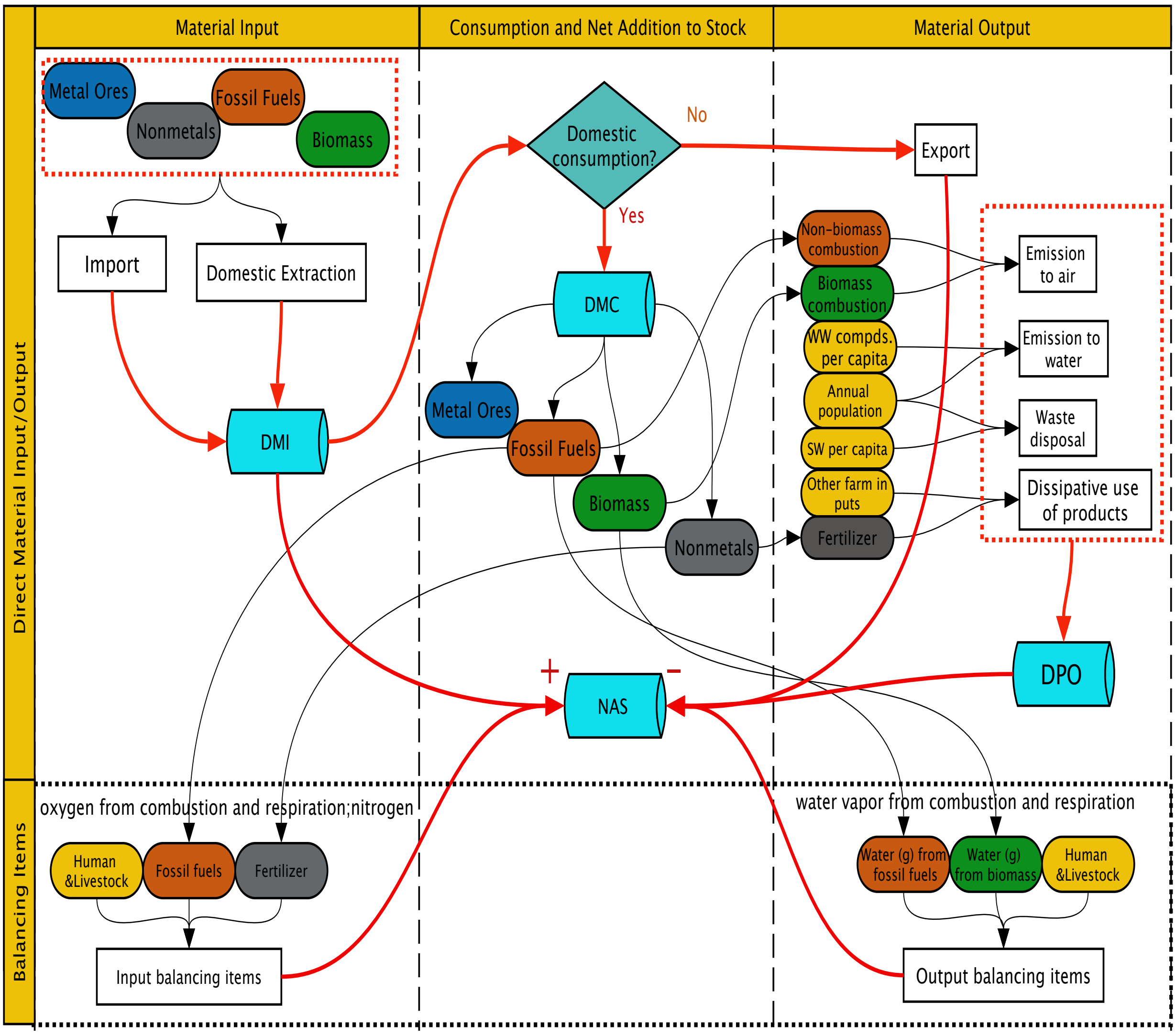


Figure 7. Process diagram for developing material flow accounts of the Philippines. The net addition to stock (NAS) is taken from the difference between the material input (+) and material output (-).

Abbreviations: DMI-direct material input; DMC-domestic material consumption; DPO-domestic processed output; NAS-net addition to stock; WW-wastewater; SW-solid wastes; compds-compounds; (g)-gas.

3.1 MATERIAL INPUT ACCOUNTS

The latest revised methodological guide and standard methods of economy-wide material flow accounting (Eurostat 2013) was used for the compilation of data for material flow accounts as shown in Table 4.

Table 4. Material categories and data sources for material flow accounts of the Philippines.

Material category	Sub-material category	Items	Data source	Data quality
Biomass	Crops	Cereals, roots, fruits and vegetables, and others	PY/PSY	Lack data of crop residues, grazed biomass
	Crop residues	Rice and corn straws, sugar cane tops and trash, coconut husks	PY/PSY	
	Grazed biomass	Grass for livestock		
	Timber	Round wood, fuel wood	PY/PSY	Wood fuels are underestimated
	Fishery	Fish from commercial and municipal fishing; seaweeds	BFAR	
Fossil fuels	Coal Crude oil Natural gas	Lignite (brown coal), hard coal Crude oil and natural gas	PY/PSY	Data reported were converted to tonnes as necessary
Metal ores	Ferrous metals Non-ferrous metals	Gold, silver, copper, iron, chromite, nickel, and others	PY/PSY	Quantity reported in concentrates and metals are converted to gross ores
Non-metallic minerals	Industrial minerals	Marble, granite, fertilizer minerals, salt, and others	PY/PSY	Data reported were converted to ton as necessary
	Construction Minerals	Sand and gravel, limestone for construction, clay, silica sand, aggregates and others		

Abbreviations: PSY: Philippine Statistical Yearbook; PY: Philippine Yearbook; BFAR: Bureau of Fisheries and Aquatic Resources

The methodological guide of Eurostat with two improvements from its first version released on 2001 (2009, 2013) is primarily based on European countries. Thus, the improvements are made as necessary and found necessary in the conditions in the Philippines which can also be appropriate for ASEAN developing country.

All materials are accounted in terms of mass flow in tonnes per year. The materials were also classified as renewable (biomass) and non-renewable (minerals and fossil energy carriers). Indirect material flows or unused materials associated to exports or imports as well as hidden materials such as overburden from mining activities were not accounted in this study.

3.1.1 Biomass

Biomass extraction data is sourced from agriculture, forestry and fisheries statistics of the Philippines. Seaweed harvest was accounted for in this study as it is planted and grown along ropes in the sea (BFAR 2009). Household and subsistence consumption of fuel wood was estimated based on data from the Household Energy Consumption Surveys conducted in 1989, 1995, 2004 and 2011 (NSO 1989, 1995, 2004, 2011). The ruminant livestock system in the Philippines comprises 90% and 99% backyard farming for cattle and water buffalo, respectively (Moog 2006). Thus, grazed biomass was based on case studies on fodder availability from cropland and grassland areas in the Philippines for water buffalo, cattle and goats (Moog 1989).

The national statistics only reports the fuel wood consumed by industry. In this research, the consumption of the fuel wood by households, which is still very common in the rural areas in the Philippines, has been estimated. The calculation of fuel wood from subsistence economy is taken from the Household Energy Consumption Survey being conducted every after five years by the National Statistics Office. From there, the conversion factors of energy sources per capita (Fuel wood, charcoal and biomass) reported by Department of Energy were used to calculate the quantity per year. Grazed biomass is also not reported in the national statistics. Utilizing the researches on the feed resources from croplands and grassland areas in the Philippines, the feed resources for carabao, cattle and goats are then estimated.

3.1.2. Fossil fuels

Data for fossil fuels including coal, crude oil and natural gas was sourced from the Philippine Statistical Yearbooks (1983–2015).

3.1.3 Metal ores

It is a well known issue of MFA that national statistics report metal production as either gross ore, concentrate or metal content (Krausmann et al. 2011; Gierlinger and Krausmann 2011). The MFA account, however, requires a run-of-mine approach and accounts for the metal ore that is extracted and delivered to the processing industry. Many MFA studies estimate gross ore from data reflecting the diverse stages of ore production and hence have a high level of uncertainty. For this study we used national data for metal to gross ore ratios of the Philippines mining sector (NSCB 1995) and consider this data quality for ore production to be superior to internationally available data.

3.1.4 Non-metallic minerals

Non-metallic minerals, mainly for the production of bricks, bitumen and concrete, and sand and gravel for structural needs in roads and rail lines, etc. are notoriously underestimated in national MFA studies (Miatto et al. 2016; Fischer-Kowalski et al. 2011). In this study, we used a novel data compilation method for non-metallic mineral accounts using physical data for cement and concrete apparent consumption combined with engineering knowledge and technical standards (Miatto et al. 2016) to crosscheck data for construction minerals found in national statistics (Philippine Yearbooks and Philippine Statistical Yearbooks 1983–2015). In each case we use the higher volume to account for construction minerals in the country.

3.1.5 Trade of materials

Import and export data were sourced from the Philippine Statistical Yearbooks (1983–2014) and Foreign Trade Statistics (1982–2014) of the Philippines and required volumes to be calculated from a suite of units reported in the statistical sources.

3.2 Material footprint accounts

Material footprints of final demand for the Philippines were accounted for by employing the approach described in Wiedmann et al. (2015) who used a global, multi-regional input-output (MRIO) model, EORA (Lenzen et al. 2013) to attribute global material extraction to final demand in the Philippines. EORA represents domestic and international monetary transactions between detailed industry sectors across 186 countries. MF is calculated by multiplying the final demand for goods and services of every country in the global dataset with multipliers representing all upstream material requirements, wherever they are sourced from globally, associated with every unit of final demand. The multipliers are established from environmentally extended global input-output analysis employing Leontief's standard input-output calculus. The material satellite account from the global dataset was replaced with material extraction data from this study to ensure compatibility between the direct and footprint accounts presented here. Thirty five (35) material extraction categories are attributed to matching product categories at a four-digit level in the OECD harmonized system employing a binary concordance matrix. The harmonized system is also used to establish concordance among industry sectors across countries. The standardized GDP accounts (real GDP at 2005 prices) is used to be consistent across countries and over time. It is important to note that in using MRIO raw material equivalents of imports were only counted if they ended up in domestic final demand; they were excluded if they serviced exports.

3.3 Material output accounts

Material output accounts allow us to measure the potential burden accompanying the release of materials to the environment. Domestic Processed Output (DPO) is accounted based on the Eurostat Manual on Accounting DPO and balancing items (Eurostat 2016). DPO is categorized in terms of three gateways: emissions to air, waste disposal, discharge to water; and two types of release processes, namely dissipative use of products and dissipative losses. Dissipative losses were not estimated herein due to the lack of data sources and basis for estimation. Categories in the accounts of DPO and the data sources of data are shown in Table 5.

3.3.1 Emissions to air

Emissions to air comprise gaseous compounds released to the environment during the process of production and consumption of materials. This accounts for emissions from biomass combustion and other non-biomass sources. Calculation of biomass combustion is based on the consumption of wood fuel and charcoal. We utilized country-based emission factors; otherwise we used those of IPPC 2006 to calculate carbon dioxide emissions. On the other hand, a reference or top-down approach (UNDP and GOP 2011; Francisco 1996) was utilized to estimate gaseous emissions from other non-biomass sources. However, in expressing the quantity of the compounds in mass units, the obtained amounts in metric tonnes were not converted into global warming potential measured as CO_2 equivalents.

Table 5. Estimation and sources of data for domestic processed output (DPO) accounts.

Categories	Sub-categories	Calculation	Data Sources
Emissions to air	1. Biomass combustion: charcoal, wood fuel 2. Excluding biomass: a. Domestic production of crude oil, coal, natural gas b. Import of crude oil, coal, petroleum products c. Industry sector such as cement and limestone production	Calculation of carbon dioxide based on Guidelines for National GHG Inventories[1]. Emission factors are also taken from this guide.	Philippine Statistical Yearbooks
Waste disposal	Municipal and Industrial wastes	Estimation based on per capita solid wastes production	NSWMC MMDA reports
Emissions to water	1. Nitrogen (N) 2. Phosphorus (P) 3. Other substances and (organic) materials	Per capita discharge of pollutants to water	Philippine Statistical Yearbooks PSA 2014 Orbeta and Indab 1993 Amaya et al. 2012
Dissipative use of products	Organic fertilizer (manure)	Number of livestock and emission factor	Philippine Statistical Yearbooks IPCC 2006 (Asia)
	Mineral fertilizer and pesticides	Consumption data	Philippine Statistical Yearbooks

[1]Tracking Green House Gases: An Inventory Manual for Philippines, UNDP and GOP 2011.
Abbreviations: NSWMC-National Solid Wastes Management Council; MMDA-Metropolitan Manila Development Authority; PSA-Philippine Statistical Agency; IPCC-International Panel for Climate Change

3.3.2 Waste disposal

Until the enactment of the Solid Wastes Management Act (SWMA) of 2000, open dumpsites served as final disposal sites of usually unsegregated solid wastes in the Philippines. Despite the stipulated closure of open and controlled dumpsites, and the construction of sanitary landfill in policy on solid waste management, progress has been slow. More than a decade after the Act's implementation, solid waste disposal facilities are still comprised primarily of open dumpsites (61.2%) and controlled dumpsites (34.4%), and a slow growing number of sanitary landfills (4.4%) (NSWMC 2012).

Eurostat (2013) refers to waste disposal as the uncontrolled disposal of wastes to landfills. Landfills are defined as a deposit of wastes into or onto land, either with the use of engineered landfill and/or stored in temporary disposal sites for over one year. Based on the previous solid waste management in the Philippines, we assumed that all solid wastes generated are released back to the environment. We based our estimation on per capita solid wastes (ADB 2003; NSWMC 2015). Accounts for municipal and industrial wastes are based on waste characterization studies (NSWMC 2015).

Material recycling refers to materials recovered from waste and converted to new usable materials (Eurostat 2016). In the Philippines, recycled material refers to post-consumer material that has been recycled and returned to the economy. However, records of recycling rates only account for recovered recyclable materials or those that have been collected and diverted away from final disposal sites (ADB 2003; NSWMC 2012; MMDA 2014). Mixed solid wastes are hauled to material recovery facilities (MRF) where manual segregation is done before final disposal to sanitary landfill or dumpsites. MRFs promote the recovery of material by-products that can be processed or used as raw materials in the manufacture of recycled products. With MRF in place and actively operating in key cities in the Philippines, the recycling rate in Manila alone increased from 6% in 1997 to 38% in 2014 (MMDA 2014). Thus, data on waste recycling in Metro Manila are deducted from the annual amount of disposed solid wastes.

3.3.3 Emissions to water

Substances that are released to natural water by human activities after or without passing waste treatment are accounted for under this category. These compounds include nitrogen (N), phosphorus (P), heavy metals, organic materials, and dumping of materials at sea. Data on water pollutants is reported in terms of concentration (quantity per volume) in water bodies; such data does not provide the quantity of pollutants actually released from sources. While the quantity of these materials is not accounted for in national statistics, estimation is based on environmental reports and published research in the Philippines (Orbeta and Indab 1993; PSA 2014; Amaya et al. 2012).

3.3.4 Dissipative flows

Materials dissipated into the environment in the process of utilization such as organic and mineral fertilizers, compost, pesticides and seeds are accounted for in this category. Estimation is based on the consumption of these materials (fertilizer and pesticides), while organic fertilizer is estimated based on the factor (IPCC 2006) and the number of livestock per year (NSO 1990, 2007, 2014).

3.4 Balancing items and Net Addition to Stock

Balancing items account for material inputs and outputs that are not sufficiently counterbalanced in the respective sides of the material balance. The input side accounts for oxygen from combustion processes, and respiration of humans and livestock, production of ammonia from Haber-Bosch process (Eurostat 2016). Being a net beverage importer (PSA 2016), the water utilized for domestic production of exported beverages was not included herein. Estimation of oxygen from respiration is based on factors for oxygen demand (Eurostat 2016), population and number of livestock per year in the Philippines (NSCB 1990, 2007, 2014; PSA 2015). Oxygen from combustion processes is estimated by getting the sum of the amounts of compounds emitted to air in DPO and the oxygen required for combustion of hydrogen (H) contents of energy carriers resulting in emissions of water vapor (H_2O), deducted from the intrinsic oxygen content of fossil energy carriers. Nitrogen for Haber-Bosch processes or the reaction of nitrogen obtained from the air and hydrogen from water and natural gas to produce ammonia are estimated based on fertilizer production data. The balancing items are calculated based on the following chemical equations:

Combustion: $C_xH_y + O_2 \rightarrow CO_2 + H_2O$

Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + H_2O$ + usable energy

Haber-Bosch processs: $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Balancing items on the output side account for water vapor from combustion and gases from respiration of humans and livestock and excorporated water from biomass products. Data for the estimation is taken from water vapor from the moisture content of consumed fossil fuels and from the oxidized hydrogen component of consumed fossil energy carriers (NSCB 1983, 1987, 1995, 2000, 2005, 2010, 2014; PSA 2015) and factors of water vapor content per energy carriers (Eurostat 2016). Similarly, the accounts for CO_2 and water respiration are taken from population and number of livestock (NSCB 1990, 2007; PSA 2015) and metabolic CO_2 and H_2O production data (Eurostat 2016).

New construction materials are used in buildings, highways, and other infrastructure that supports economic activities. Materials are added to the economy's stock each year as gross additions while demolished buildings or discarded materials are removed from stocks. Net addition to stock (NAS) is the balance between gross additions to and removal of stocks. We utilize the indirect calculation of NAS, where domestic processed output, exports and the water vapor emitted during chemical processes are subtracted from the direct flow of materials into the economy (DMI) together with air inputs (Eurostat 2001; Matthews et al. 2000).

3.5 Indicators

Aggregate indicators can be derived from the material flow accounts and shown herein as extensive and intensive indicators. Table 6 shows the brief description and calculation of these indicators.

3.5.1 Extensive indicators

Extensive indicators derived in this study are enumerated in Table 6. Indicators include domestic material consumption (DMC) and physical trade balance (PTB). PTB is calculated by subtracting material exports from physical imports. DMC gives a territorial account that refers to the total quantity of inputs (less exported materials) used in a national economy (Eurostat 2001). The components of DMC are domestic extraction (DE) and traded commodities (imports and exports). DE refers to raw materials extracted or harvested within the domestic environment. DMC is then calculated by getting the sum of DE and PTB (DMC= DE + PTB or DMC = DE + physical imports – physical exports).

Table 6. Material flow indicators utilized in this study.

Indicator	Brief Description	Calculation
Extensive Indicators		
Domestic Extraction, DE	Materials taken from domestic environment for processing and utilization in the socio-economic system.	Biomass + Fossil energy carriers + Non-metallic minerals + Metallic ores
Direct Material Input, DMI	Materials that enter the socio-economic system.	DE + Import
Domestic Material Consumption, DMC	Accounts the materials required by socio-economic system to sustain its needs and growth; it also refers to production indicator	DMI – Export
Material Footprint	MF refers to the global allocation of primary material extraction to measure the appropriation of natural capital and resources to the final demand of an economy; it is regarded as the consumption indicator	$MF = DE + RME_{import} - RME_{export}$ RME:Raw Material Equivalent
Domestic Processed Output, DPO	Outflows of materials occur during processing, manufacturing, consumption and final disposal.	Emission to air + Emission to water + Discharge to soil + Dissipative use of products
Physical Trade Balance, PTB	Measures the trade surplus (resource provider, negative value) or deficit (resource dependence, positive value) of the economy.	Import – Export
Net Addition to Stock, NAS	Measures the economy's physical growth, it accounts the quantity (in weight) of materials remain for a longer period in the socio-economic system after the old materials and durable goods are removed as wastes or exported to other socio-economic system.	DMI +Air Inputs – (DPO + water vapor + Exports)
Intensive indicators		
Material Efficiency or Material Intensity	It refers to the quantity of material required for every unit of value. The economy has become resource efficient when the value is seen to be decreasing through time.	Intensity/efficiency with respect to resource: input: DMI/GDP production: DMC/GFP consumption: MF/GDP output: DPO/GDP
Material Productivity	Expresses how much an economy earns per unit of resources. The higher its value, the greater is the productivity of the economy.	Productivity with respect to resource: input: GDP/DMI production: GDP/MF consumption: GDP/MF output: GDP/DPO
Material flow with respect to size of territory	Material burden of the available resources to the environment	DE/total land area

References: Eurostat 2009; Matthews et al. 2000; Weidmann et al. 2015

DE and DMC are commonly used as proxies of local environmental pressure because of the disturbance to the natural environment that may occur during the process of extraction and transformation of materials to usable forms. DMC also reflects the potential for waste from the socio-economic system (Giljum et al. 2014a; Marra Campanale and Femia 2013). Imports and exports, in physical units, show the amount of primary material and final goods that are exchanged between countries. On the other hand, PTB indicates whether an economy is a net provider of resources shown by a negative PTB value (Imports < Exports) or resource dependent as implied by a positive PTB (Imports > Exports).

Materials embodied in the manufacture of final products are referred to as indirect material flows (Fischer-Kowalski et al. 2011; Eurostat 2001; Bruckner et al. 2011). Embodied materials in imports and exports should be taken into account due to the prevailing trend of externalization of environmental pressure by developed countries, which results in increasing environmental intensity in developing countries brought about by growing export of materials (Bruckner et al. 2011). This is measured by the material footprint (MF) indicator. MF is calculated based on the sum of DE and raw materials embodied in imports less than raw material embodied in exports. MF refers to the global allocation of primary material extraction to measure the appropriation of natural capital and resources to the final demand of an economy (Giljum et al. 2014b; Wiedmann et al. 2015; Simas et al. 2017). The material footprint approach employs a uniform system boundary to domestically sourced materials and the material requirements of imports and exports.

The domestic processed output accounts the material input that flows back to the domestic environment. Export is that accounted in DPO since it turns out as waste in the country where it has been utilized (Matthews et al. 2000).

3.5.2 Intensive indicators

Intensive indicators present the material efficiency of the economy, expressed as material intensity and material productivity. Material efficiency is expressed here as the material intensity of economic activity using DMC as the numerator for standard material intensity accounts, MF as the numerator for trade-adjusted material intensity accounts, and GDP as the denominator. The exchange rate based

GDP (at 2005 prices) is taken from the United Nations Statistics Division (UNCTAD 2016). In line with previous studies of material efficiency, we preferred exchange rate based GDP for the measure of production over a PPP approach (World Bank 2016; Schandl and West 2010). Material intensity is hence expressed as DMC/GDP and adjusted material intensity as MF/GDP.

3.6 Lorenz curve and Gini coefficient

The quantitative perspective in the distribution of resources with respect to the area coverage of each province is taken into account by calculating the Gini coefficient and plotting a Lorenz curve. The Lorenz curve and Gini coefficient are economic tools that have been utilized in physical measures such as ecological footprint (White 2000; 2007) as well as in global material consumption (Steinberger et al. 2010). Lorenz curve is a graphical presentation of the inequality and the Gini Coefficient is the value that ranges from 0 signifying absolute equality to 1 denoting absolute inequality. The Gini coefficient is calculated from the constructed Lorenz curve. The Lorenz curve is constructed by arranging the percentage of DE per province per percentage of land area in increasing order. The cumulative percentage of DE is plotted with respect to the cumulative percentage of land area.

The points in the Lorenz curve express the cumulative fraction of land area (on horizontal axis) producing or having a cumulative fraction of resources (on vertical axis). The Lorenz curve is given by $\boldsymbol{y_n = L(x_n)}$

where $\boldsymbol{x_n = \sum_1^n A_n / A_{Phil}} \quad \boldsymbol{y_n = \sum_1^n R_{i,n} / R_{i,Phil}}$

A_n is the land area of any province n; $R_{i,n}$ refers to the domestic extraction of material category i of any province n.

The area under the Lorenz curve is then calculated using the equation (Dorfman 1979; Steinberger et al. 2010): $\boldsymbol{G = 1 - 2\int_0^1 L(x)dx}$

3.7 Environmental Kuznets Curve

Environmental Kuznets Curve (EKC) utilizes the inverted-U shaped curve to show the relationship between economic growth, usually indicated by GDP and environmental pressure or degradation. This assumes that on the early phase of economic growth with rapid industrialization, the pollution or damage to the environment increases (Stern 2004). When the income and economy has risen and reached a certain turning point, the people become particular of having a healthy environment, thus imposing regulations and standards to abate the pollution and impacts of economic activities (Auci and Vignani 2013). Studies such as Cleveland and Ruth (1998) and Stern (2004) showed the Environmental Kuznets Curve for materials, with an assumption that at the initial stage of economic development, the intensity of use increases and tends to decrease as the economy matures and income improved. Environmental Kuznets Curve was utilized to ascertain the relationship between the economic growth and pressure the socio-economic has to the environment through the DPO indicator. Previous literature points out DMC as pressure indicator, while DMC represents the future wastes to be released back to the environment, DPO represents the actual volume of discharge of wastes to the environment as a result of economic activities at any given year.

The relationship of economic growth in the Philippines and output to the environment is presented by plotting the GDP US$ (constant 2005) per capita (World Bank 2017) and DPO/capita as independent and dependent variables, respectively.

3.8 IPAT: Driving Factors

With the use of an IPAT analysis, the drivers of resource consumption, or impact (I), in the Philippines are determined based on three factors: population (P), affluence (A) and technology (T). Affluence is defined as GDP/capita while Technology is expressed as resource intensity (DMC/GDP). These factors provide the IPAT identity ($\boldsymbol{I} = \boldsymbol{P} \times \boldsymbol{A} \times \boldsymbol{T}$, Commoner 1972; Erlich and Holdren 1972). We look at the percent changes of these factors at the beginning of a period compared to its end, which are approximated by log-transformations to the equation. By definition of this transformation, the values of the changes in P, A, and T sum to the change in I in that period, making it straightforward to distinguish the relative influence of each driver on the total change in DMC.

3.9 Data access and quality

The physical accounts are established primarily from published Philippine statistics data. National statistics data offers reliability and good data quality for input flows accounts. The Philippine Yearbooks and Philippine Statistical Yearbooks are compiled and published annually; books from 2012 onwards are available online while older publications are available in print. National data on extraction of fossil energy carriers, non-metallic minerals and metal ores are reported on an annual basis. The Philippine Yearbook provides detailed data within the minerals category, distinguishing metal ores from non-metallic minerals. Further, construction minerals within non-metallic minerals are also distinctly reported. The Philippine Yearbook also presents these data in provincial and regional levels. Under the biomass category, while grazed biomass and crop residues are not reported in the national statistics, there is a range of published researches that provide reliable references for its estimation.

Output flows provide a challenge in accounting. Data on emissions to air are not yet accounted for annually. We utilized the guidelines in the GHG Inventory Manual for Philippines (UNDP and GOP 2011) to calculate gaseous emissions from the energy and industry sectors. The national statistics provide data on air and water quality at certain given times. Air emissions and wastewater discharges are reported in terms of concentration of compounds (ppm or mg/L). While this provides data on the quality of the natural environment at a glance, this method of reporting does not account for the quantity of that specific pollutant or compound released and already present in the atmosphere or bodies of water. Materials in dissipative flows such as manure are estimated based on IPCC 2006 factors for Asia and the number of livestock; fertilizer and pesticide consumption are reported in national statistics.

4. Material Flow and Stock of the Philippines

To shed light on the relationship between the economy and natural resources, this research investigates the case of the Philippines, employing a material flow accounting approach based on national statistical sources. This section presents the trends of domestic extraction, trade of materials, material use, and output to environment from 1980 to 2014. It also shows the differences between territorial (production) and footprint (consumption) accounts.

4.1 Input indicators

4.1.1 Domestic Extraction

Resource extraction from the domestic environment continues to provide the majority of the material needs of the country. Domestic extraction (DE) of materials – biomass, fossil fuels, metal ores and non-metallic minerals – is an indicator of the availability of natural resources in the Philippines. Total DE increased from 274 million tonnes (Mt) (5.8 tonnes per capita) in 1980 to 598 Mt (6.0 tonnes per capita) in 2014 (Figure 8). Except for metal ores, DE of all material categories has increased, leading to a shift from dominance of biomass (53% in 1980) to non-metallic minerals (49% in 2014). The decline in metal ore extraction is attributed to various factors such as high operating and production costs accompanied by low international metal prices and domestic political issues, and worsened by natural disasters that occurred in the last quarter of the 20th century (Lyday 2000). To revitalize the mining industry, the Philippine Mining Act was instituted in 1995.

DE grew faster from the period of good governance and incorporating Millennium Development Goals into policies (2000–2014) at 5.4%, higher than the 0.2% annual growth rate during the period of political crises, and from the onset of policies focused on poverty alleviation, human development and international competitiveness (1980–2000). The higher growth rate is fueled by an increase in biomass and non-metallic minerals extraction. Non-metallic minerals, comprised primarily of sand, gravel and limestone, increased as infrastructure development emerged in the country. In a similar fashion, the extraction of metal ores started to recover when major exploration investment identified promising mineral deposits, supplying to international markets, and enabled by new policies that favor mining (Fong-Sam 2012). Fossil fuel, with a 3% share of DE in 2014, had the highest compounding annual growth rate of 7% from 2000 to 2014 due to the development of the oil and gas industry in the country from 2002, providing 20% of the country's power requirements.

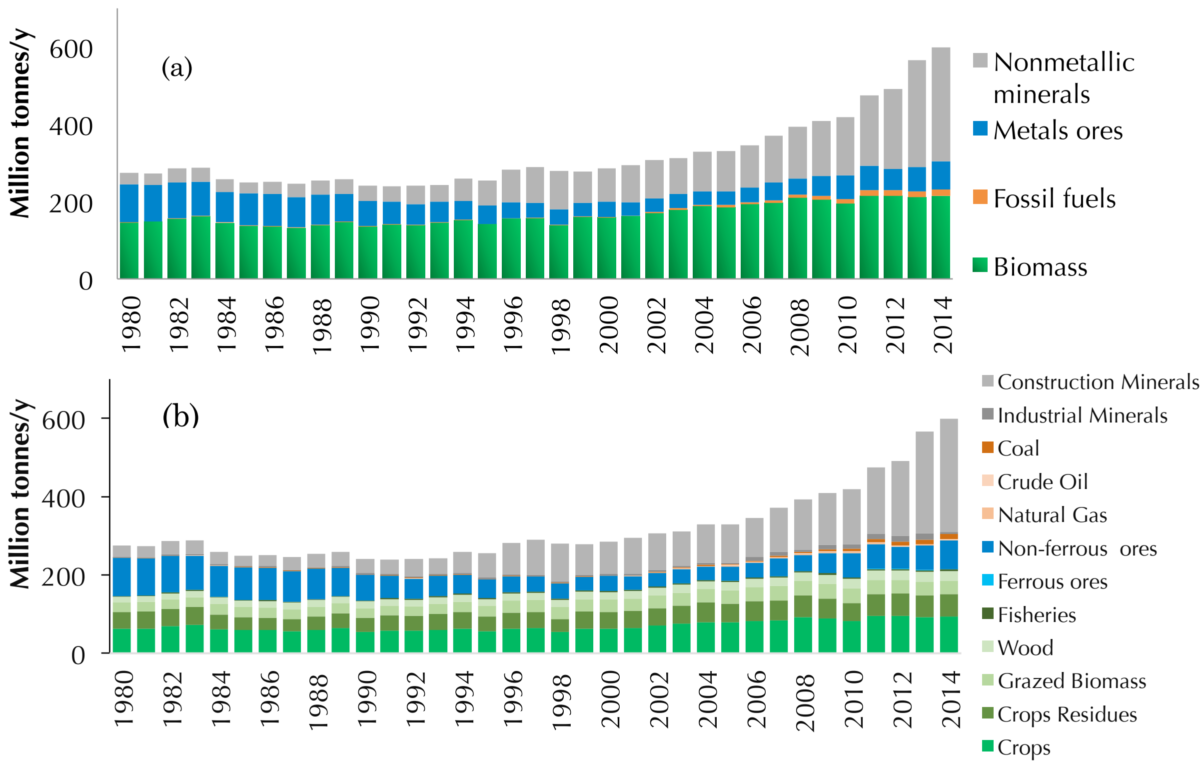


Figure 8. Domestic extraction from 1980 to 2014 shown per: (a) four main material categories; (b) 12 sub-material categories.

RESOURCES EXTRACTION PER PROVINCE IN THE PHILIPPINES

Extraction of resources has strongly supported the needs and growth of the national economy. But where do the bulk of resources come? The first step in compilation of material flow accounts per province in the country is presented in Figure 9.

In an archipelagic country such as the Philippines, supplying the needs of society through exchange of resources between geographical territories is a challenge. With limited option, people and local economies rely on the available natural resource, often resorting to resource intensive activities to support the livelihood and the economy. On average, 7 Mt of materials are extracted per province, and only five provinces have DE of more than 20 Mt. Materials under biomass such as agriculture, fishery and forestry are extracted from all of the provinces in the country at varying quantity. Negros Occidental as the main sugarcane producer in the country topped the list of source of biomass. Non-metallic minerals such as limestone and shale, silica, aggregates, dolomite, clays and sand and gravel are extracted from 79% of the provinces. Quarry of sand and gravel from rivers and mountains are commonly undertaken to support the construction industry in the provinces. Limestone quarry for cement production are also extracted from some of the provinces with Pangasinan, Rizal and Cebu as the top sources in 2013.

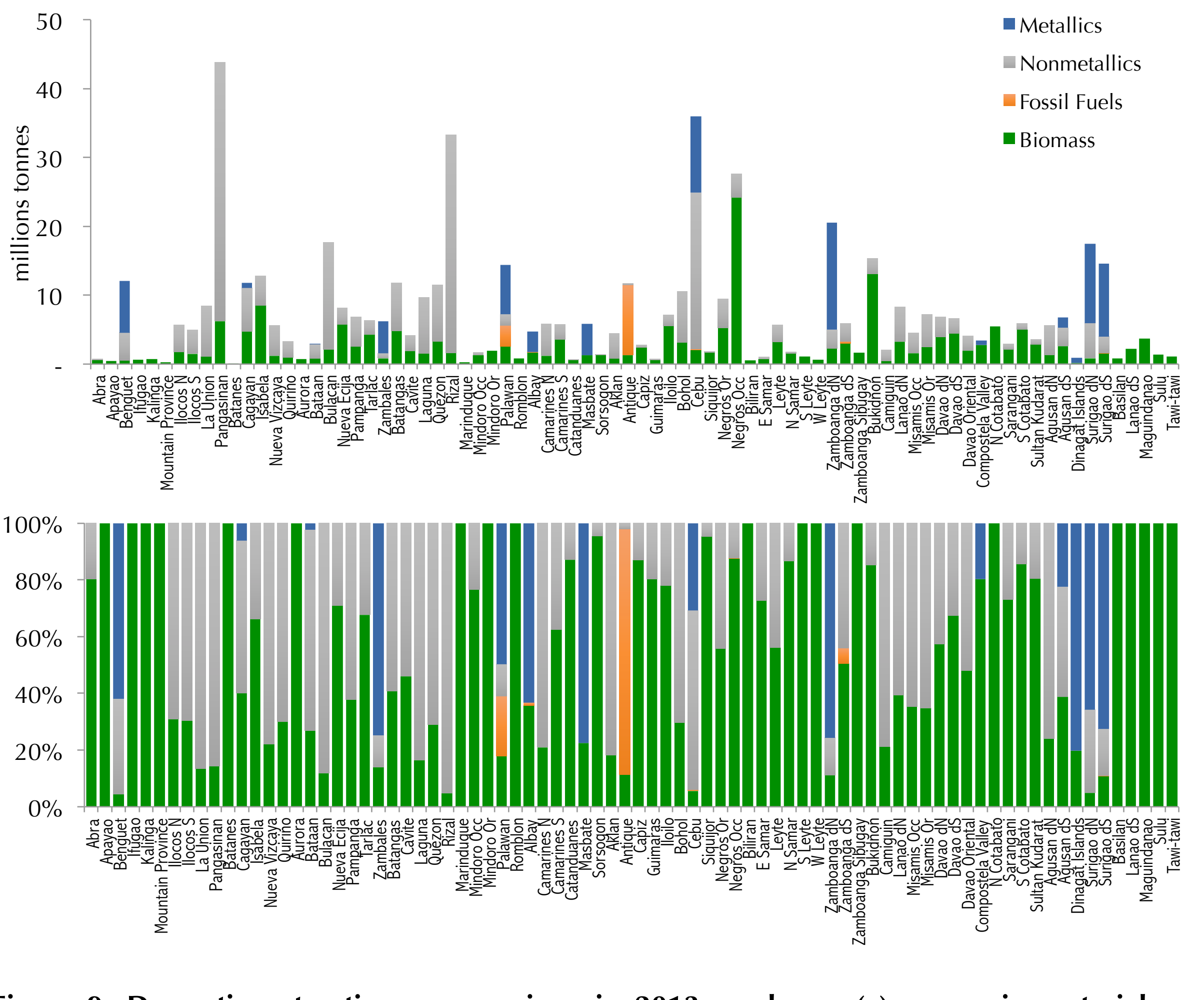


Figure 9. Domestic extraction per province in 2013 as shown (a) per main material categories (b) percentage share of each category to the total DE.

Note: The provinces are arranged based on its relative proximity to each other.

Metallic minerals are extracted from 17% of the provinces, with gold and ores of copper, chromite and nickel as the main produce. Top provinces are Surigao del Sur, Surigao del Norte, and Palawan from nickel ores; Zamboanga del Norte, Benguet and Cebu for copper concentrate and gold. Fossil fuel sources are extracted from 7 provinces in the Philippines. Coal is mainly extracted from the province of Antique, while natural gas and crude oil are solely produced from the province of Palawan. Figure 10 presents the aggregate domestic extraction from each province in the Philippines.

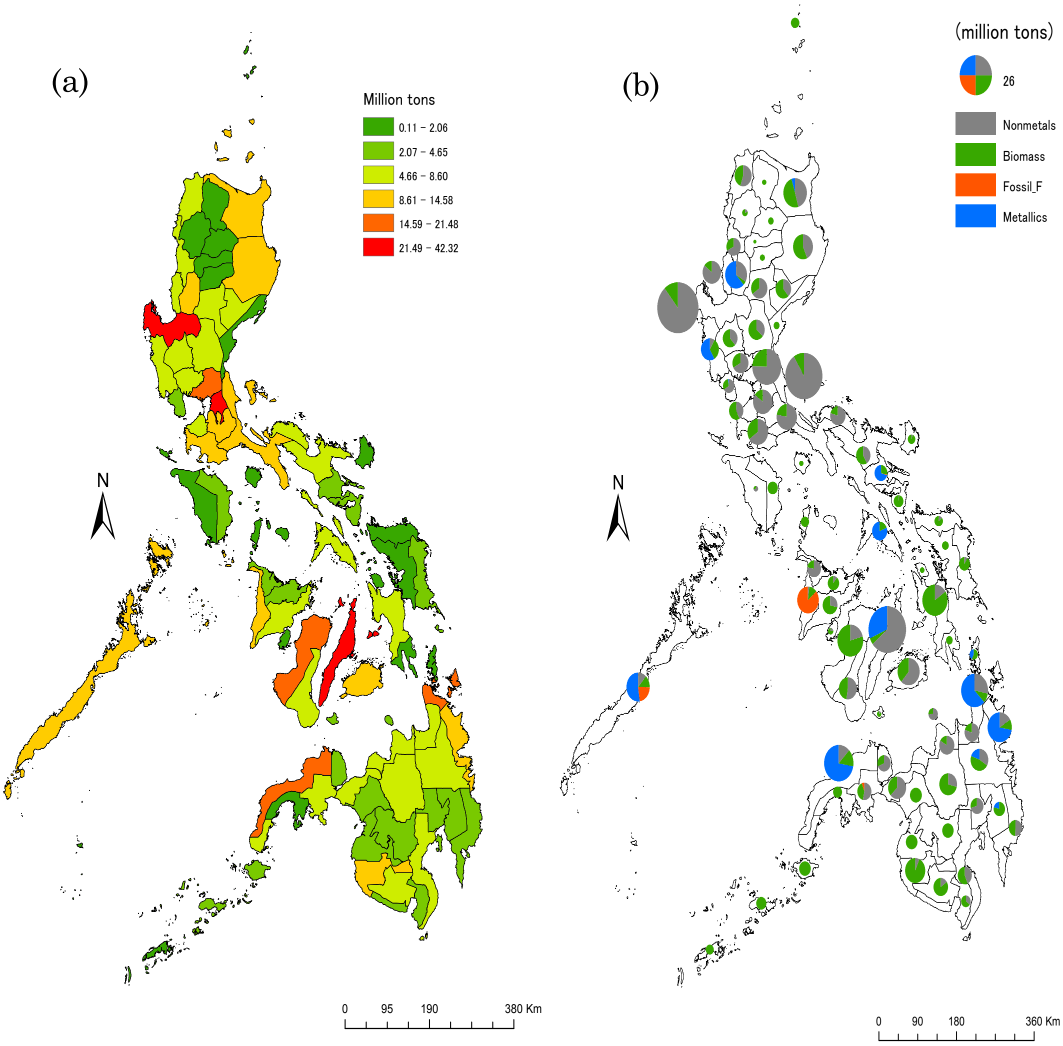


Figure 10. Map of the Philippines showing per province in terms of (a) aggregate DE; and (b) DE per material categories.

Note: The size of the pie chart varies based on the sum of the aggregates.

4.1.2 Direct Material Input

DMI as an important indicator that accounts for materials coming into the socio-economic system, increased at a cumulative growth rate of 2.4% per annum (Figure 11). Fossil energy carriers continue to be the leading material imports of the Philippines despite efforts to increase self-sufficiency in the energy sector. This shows that domestic sources cannot cope with the growing demand for energy in the country. Although the amount of biomass increased continuously, its proportion in DMI reduced from 50% in 1980 to 35% in 2014. Metal ores declined both in quantity and proportion from 35% in 1980 to 13% in 2014. Although increasing inputs were observed in 2000–2014 with a cumulative growth rate of 5% per annum, the quantity is still below that of 1980 level. On the other hand, non-metallic ores increased by tenfold, with 11% of DMI in 1980 to 45% in 2014. Non-metallic minerals are mainly utilized in the construction sector. Similarly, fossil energy carriers' inputs grew fourfold, and comprised 4% in 1980 to 7% in 2014 of the DMI.

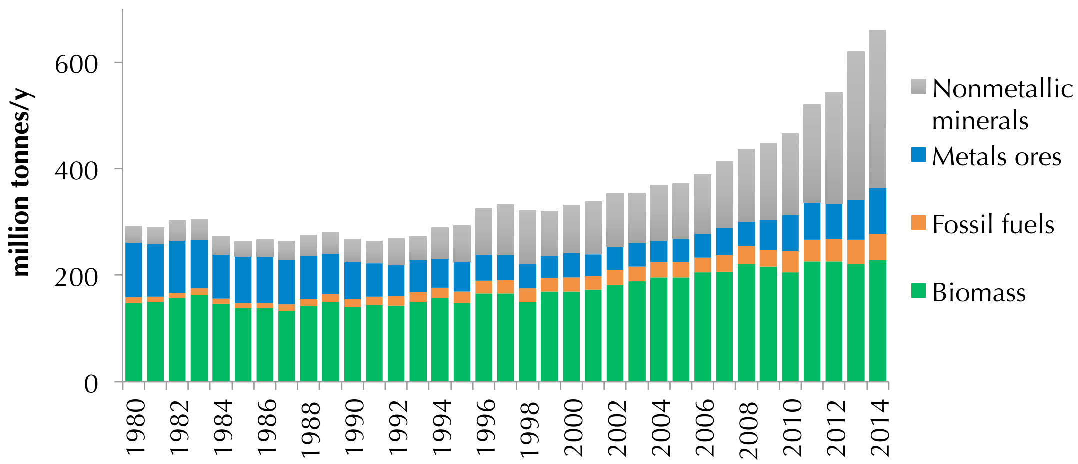


Figure 11. Direct material input (Domestic Extraction + Import) from 1980 to 2014.

4.2 Trade of materials

4.2.1 Import

Imports increased from 18 Mt in 1980 to 60 Mt in 2014 at a compounding annual growth rate of 4%, while exports grew at a rate of 6% annually, from 10 Mt in 1980 to 72 Mt in 2014. Trade liberalization policies starting in 1991 relaxed import tariffs, which increased trade. In particular, fossil fuel and biomass imports grew to support the increasing consumption of the growing urban population and their more affluent dietary and mobility requirements. Furthermore, the importation of primary materials and intermediate goods for final production has become a prerequisite for the manufacturing industry in the Philippines, which is oriented towards assembly and exports (Canlas and Nimura 2001; Aldaba 2014). Figure 12a shows the trends and changes in the import profile of the Philippines from 1980 to 2014.

4.2.2 Export

Biomass and metal ores are the country's main material exports. The Philippines used to be net exporter of biomass in the 1980s but production was unstable due to weak agricultural practices, a lack of transport infrastructure and exposure to the impact of frequent typhoons. The Philippines became a net exporter of metal ores from 2004 (Figure 12b), and exports have been growing gradually along with a growing domestic mining industry.

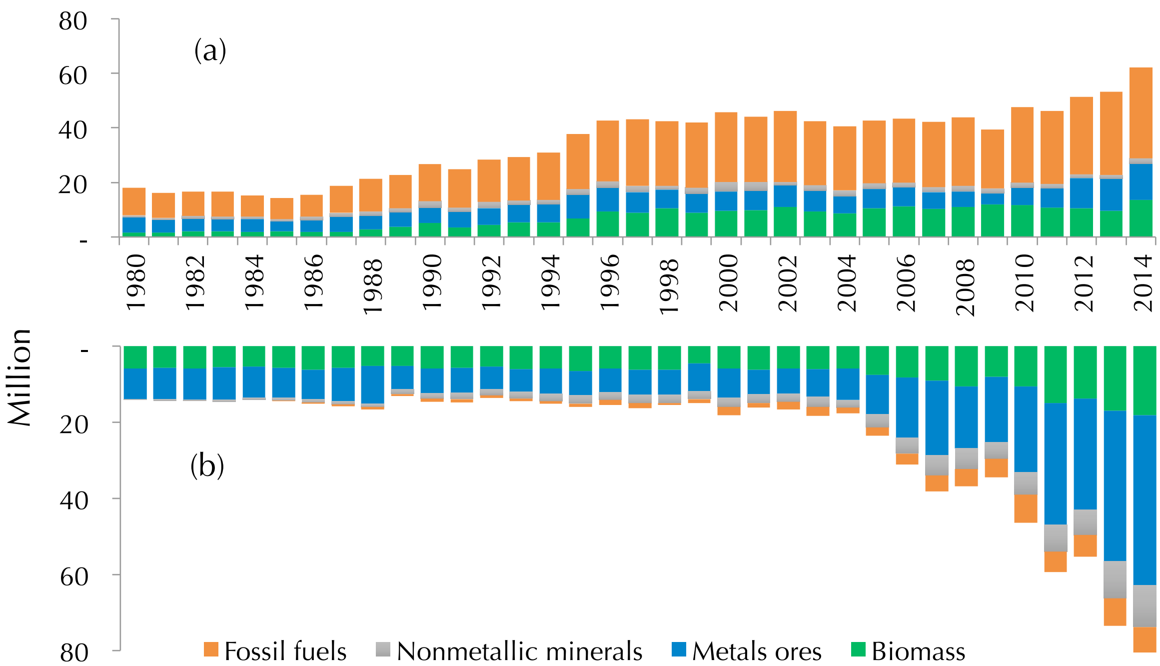


Figure 12. Trade dependence as shown by material (a) import and (b) export from 1980 to 2014.

The domestic extraction of metal ores is mainly dictated by external market demand, not by domestic processing and consumption. Its share in total merchandise exported increased from 1.5% of all monetary exports in 1998 to 6.6% in 2014 (World Bank 2016). Despite the increasing number and area of operations for metal ore production, mining and quarrying comprise a meager contribution of 1% of total GDP and accounted for 0.6% of employment in 2014 (PSA 2015). This demonstrates the negligible contribution of mining to human development in a situation of weak institutions and low capacity for value adding.

4.3 Production and consumption indicators

4.3.1 Domestic Material Consumption (Production based indicator)

DMC (domestic extraction + imports – exports) increased from 282 Mt (6.0 tonnes per capita) in 1980 to 581 Mt (5.9 tonnes per capita) in 2014 as shown in Figure 13, with a compounding annual growth rate of 2.2%. In the absence of substantial trade, DMC and DE show similar trends, except for the increased fossil fuels component in DMC, supplied by imports.

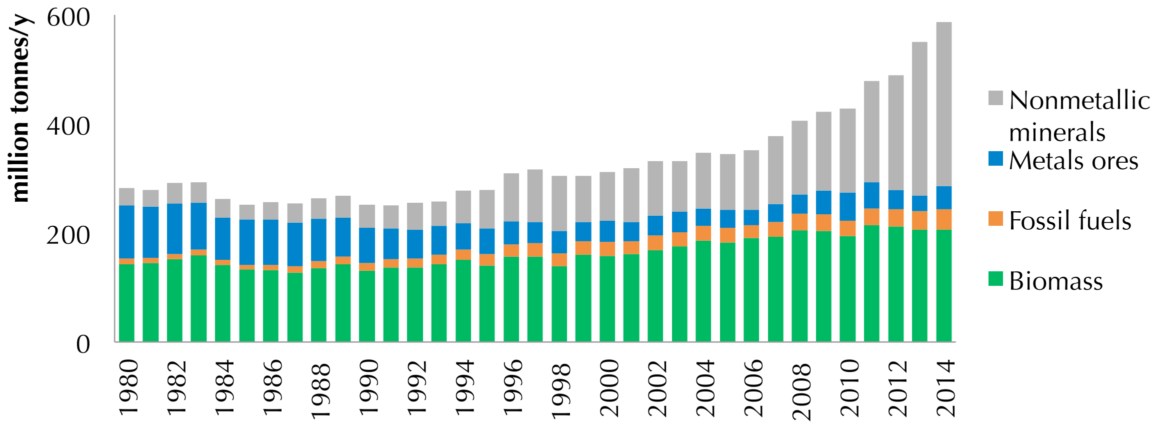


Figure 13. Domestic material consumption from 1980 to 2014.

Notably, the consumption of non-metallic minerals rose at a faster rate during the last decade, which can be attributed to changing macroeconomic policies. The Build-Operate-Transfer (BOT) policy in 1990 attracted foreign investment in infrastructure projects, and the Philippines have become a frontrunner in the implementation of BOT projects compared with other developing countries in Asia (Canlas and Nimura 2001). As an example of the impact of the BOT policy, the floor area of private buildings and the number of new residential units financed by the government has grown six fold since 1990. Over the same period, fossil fuel consumption grew at a compounding annual growth rate of 5.8% from 1990 to 2000 due to increased motorization of private transport and the power needs of new industries.

From 2000 to 2014, non-metallic minerals consumption rose at an average rate of 9.1%, while fossil fuel consumption only grew by 2.9%. The modest growth in fossil fuel consumption amidst the active economy can be attributed to national policies that regulate the power and energy industries. The Electric Power Industry Reform Act (EPIRA) in 2001, as well as the Philippine Energy Plan 2007–2014, provided for the attainment of 60% energy self-sufficiency beyond 2010 through intensifying development of renewable energy sources, the use of alternative fuels and enhancing energy efficiency and conservation. Energy self-sufficiency went well beyond the target up to 2012 but decreased to 56% in 2013–2014, when the increasing demand was no longer adequately provided from indigenous energy sources (PSA 2015).

4.3.1 Material Footprint (Consumption based indicator)

Material footprint (MF) provides an additional perspective on resource use, correcting direct material flows for materials embodied in trade. The total material footprint of the Philippines increased from 198 Mt in 1990 to 364 Mt in 2010 (Figure 14).

MF has been dominated by biomass, but with a declining share from 55% (109 Mt) in 1990 to 44% (159 Mt) in 2010. Non-metallic minerals increased from 32% (63 Mt) in 1980 to 42% (155 Mt) in 2010. Similarly, fossil fuels increased from 10 Mt (5%) to 33 Mt (9%), and metal ores went up from 15 Mt (8%) to 17 Mt (5%).

About 40% of the overall material footprint occurred for final demand of manufacturing goods, followed by 25% for construction expenditure. Agricultural products attracted between 19% to 27% of overall footprint and services 5% to 7%. Products and services from mining, energy and transport attracted low material footprints of 2% to 3%.

In recent years, the Philippine economy has shown strong economic growth driven by household consumption, government expenditure and public and private investment. Translating this from monetary terms to the physical economy shows that the final demand of households (53%) has the biggest share of material footprint followed by capital investment (46%) while government final demand accounts for only 1%.

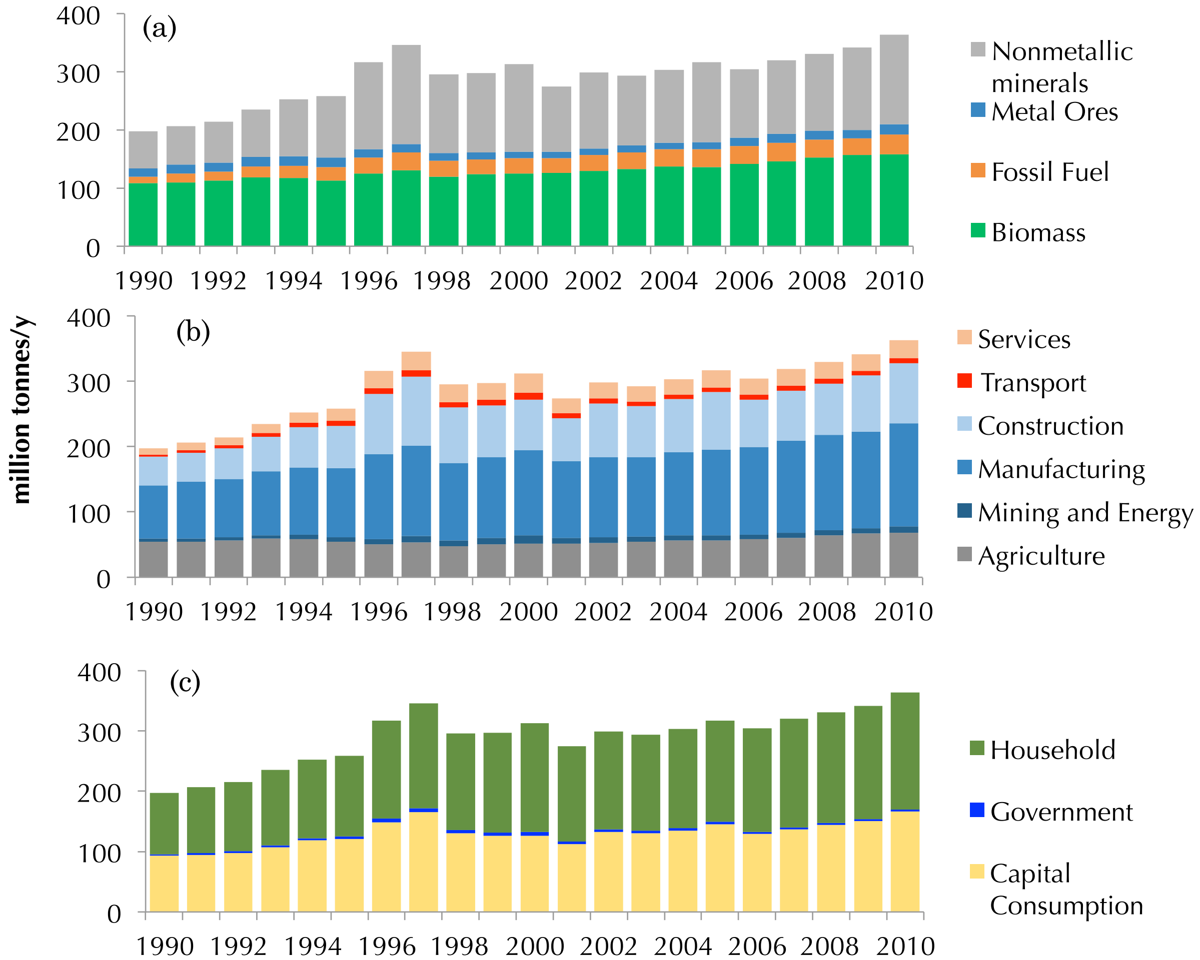


Figure 14. Material footprint from 1990 to 2010 in terms of (a) main material categories and (b) economic sectors (c) aggregated by final demand.

The material footprint of household consumption is comprised primarily of biomass (62%), reflecting that the typical Filipino household puts priority on providing basic needs such as food and uses light materials (biomass-based) for house construction and biomass-based energy sources such as fuel wood and charcoal. In 2010, 52% of the perimeter walls of occupied housing units were made of wood and other light/biomass-based materials, a decline from 64% in 2000 (PSY 2005, 2014). Lesser MF share was accounted for by non-metallic minerals (23%), fossil fuels (11%) and metal ores (3%).

4.4 Output Indicators

Aside from exports, at which raw, semi-processed materials or finished products are supplied to trade partner nations of the Philippines, some resources are reduced to waste and released back to the environment. Accounted for as DPO, an increasing trend was observed from 96 Mt to 263 Mt from 1980 to 2014, with a cumulative growth rate of 3% per annum. The DPO is presented in terms of the main categories considered in this study (Table 7) and gateways to the environment (Figure 15).

Table 7. Domestic processed output (DPO), in million tonnes.

	1980	1990	2000	2010	2014
Emissions to air	82	103	132	172	231
Waste disposal	5	7	10	14	16
Emissions to water	2	3	3	4	4
Dissipative use of products	7	8	10	11	11
DPO Total	96	120	156	201	263

Emissions to air comprise the bulk of outflow to the environment at 89% in 2014, with carbon dioxide as the major compound (94%), but the increase in other compounds such as carbon monoxide and sulfur dioxide emissions has been observed to grow faster at a rate of 4% and 6% per year, respectively. Carbon dioxide is released mainly from the burning of fossil energy carriers and industries such as cement production. The increasing consumption of fossil energy sources offsets the increasing supply of renewable energy sources in the Philippines. In 2014, renewable energy sources such as geothermal, hydro, biomass, solar and wind supplied 39% of the energy supply mix of the country. The remaining are nonrenewable energy sources, mainly are imported energy (44%) such as oil and coal (PSA 2015). The cement and limestone production is the main industry contributing to the GHG of the Philippines. The cement industry primarily cater to the growing cement demand due to the increasing public and private construction (CeMAP 2015).

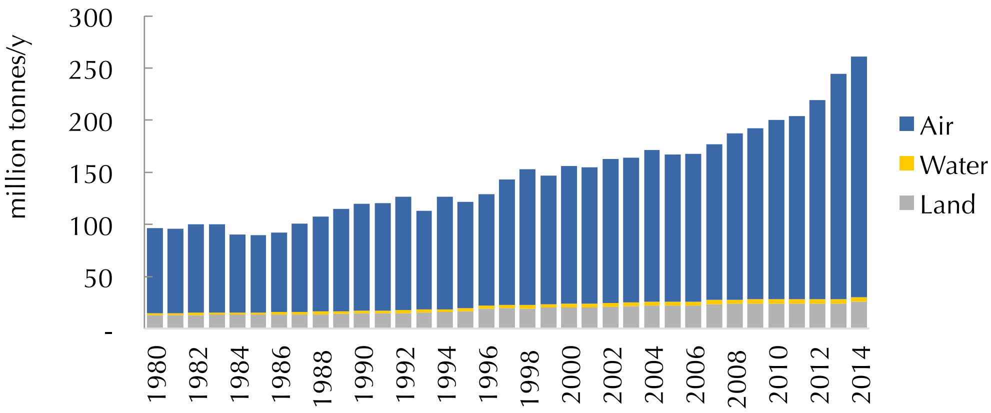


Figure 15. Outflow of materials (DPO) from socio-economic system to environment through the three environmental gateways.

Solid wastes management is one of the environmental challenges being faced by developing nations (Moriguchi and Hashimoto 2016) and is a prevalent issue in the Philippines (ADB 2003). Wastes deposited to land account for 5% of DPO, with the highest cumulative growth of 3.3% per annum. This is despite of the enactment of policy on solid waste management in 2000. Under this policy, sanitary landfills are to be constructed and used as final waste disposal in lieu of open dumpsites. However, as of 2012, sanitary landfills constituted only 4% of final disposal facilities, while 61% are open dumpsites and 34% are controlled disposal facilities (NSWMC 2012). Furthermore, the lack of waste segregation at source and final disposal sites compound the solid waste problem. Recycling rates in the Philippines are reported based on the percentage of waste that is recovered and diverted away from final disposal facilities. Recovered recyclable materials include paper, plastic, metal, glass and others sold to dealers while large commercial industries sell directly to dealers. Data, however, on the quantity of recovered products that undergo recycling processes is lacking.

Similarly, there is also a predominant issue of pollution to water. While wastewater treatment facilities are required in large commercial buildings, industrial plants, as well as residential buildings, as stipulated in the Philippine Clean Water Act of 2004, the bulk of wastewater generated from residences and houses are directly discharged to land and bodies of water without undergoing treatment. Emission or discharge to water increased threefold from 5 Mt in 1980 to 16 Mt in 2014. Organic compounds from domestic wastewater comprised 80% of the pollutants to water.

Moreover, in agricultural country such as Philippines, the farm inputs such as fertilizers and pesticides applied to crops at various intensity and concentration to increase harvests mainly constitute the dissipative use of products. We have accounted these materials under the dissipative use of products, and it comprises 4% of DPO. These substances exit to either bodies of water, land or air without being monitored or regulated.

4.5 Balance indicators

4.4.1 Net Addition to Stock

Net addition to Stock (NAS) grew modestly at 1.7% per annum as shown in Figure 16. In 2014, 46% of material inputs were stocked in socio-economic systems, a decline from 59% in 1980.

Notwithstanding the increased consumption of non-metallic minerals for building physical infrastructure, more than half of the annual material inputs in society are immediately released back to the environment. Despite increased consumption of non-metallic minerals for building physical infrastructure, outputs to the environment are greater due to increased consumption of fossil energy carriers and biomass.

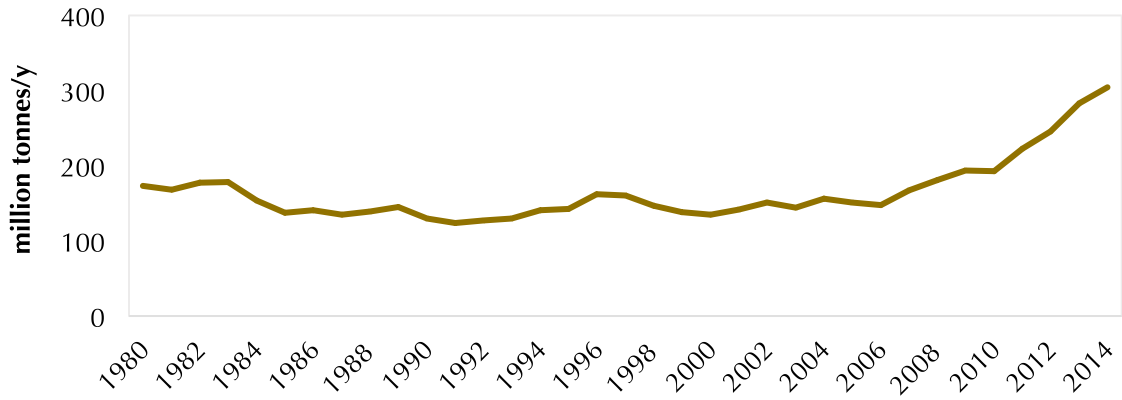


Figure 16. Net addition to stock from 1980 to 2014.

4.4.2 PHYSICAL TRADE BALANCE

The PTB shows that the country moved from being a net importer of materials (7.4 Mt in 1980) to a net exporter of materials (–11.6 Mt in 2014) (Figure 17). With a negative value of PTB from 2012 onwards, i.e. exports greater than imports, the Philippines joined other countries such as Laos (UNEP 2011b) and Myanmar (Maung et al. 2014) in the Southeast Asian region that are net providers of resources to rest of the world.

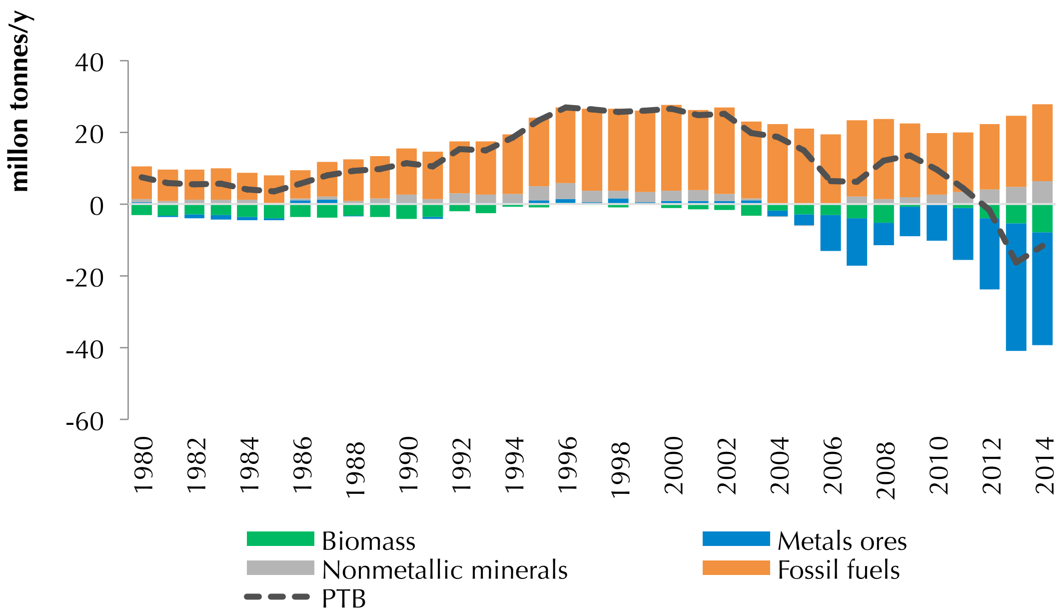


Figure 17. Physical trade balance from 1980 to 2014. Negative values reflect export.

5. Socio-Economic Metabolism of the Philippines

5.1 Extensive view of socio-metabolic transition

Figure 18 provides a full picture material balance of the Philippines for 1980 and 2014. The domestic environment provides 90% of the resource requirements of the socio-economic system of the Philippines. Imports provide the remainder of the material requirements; these are composed mainly of fossil fuel energy sources as well as processed biomass and finished products of metallic minerals.

(a)

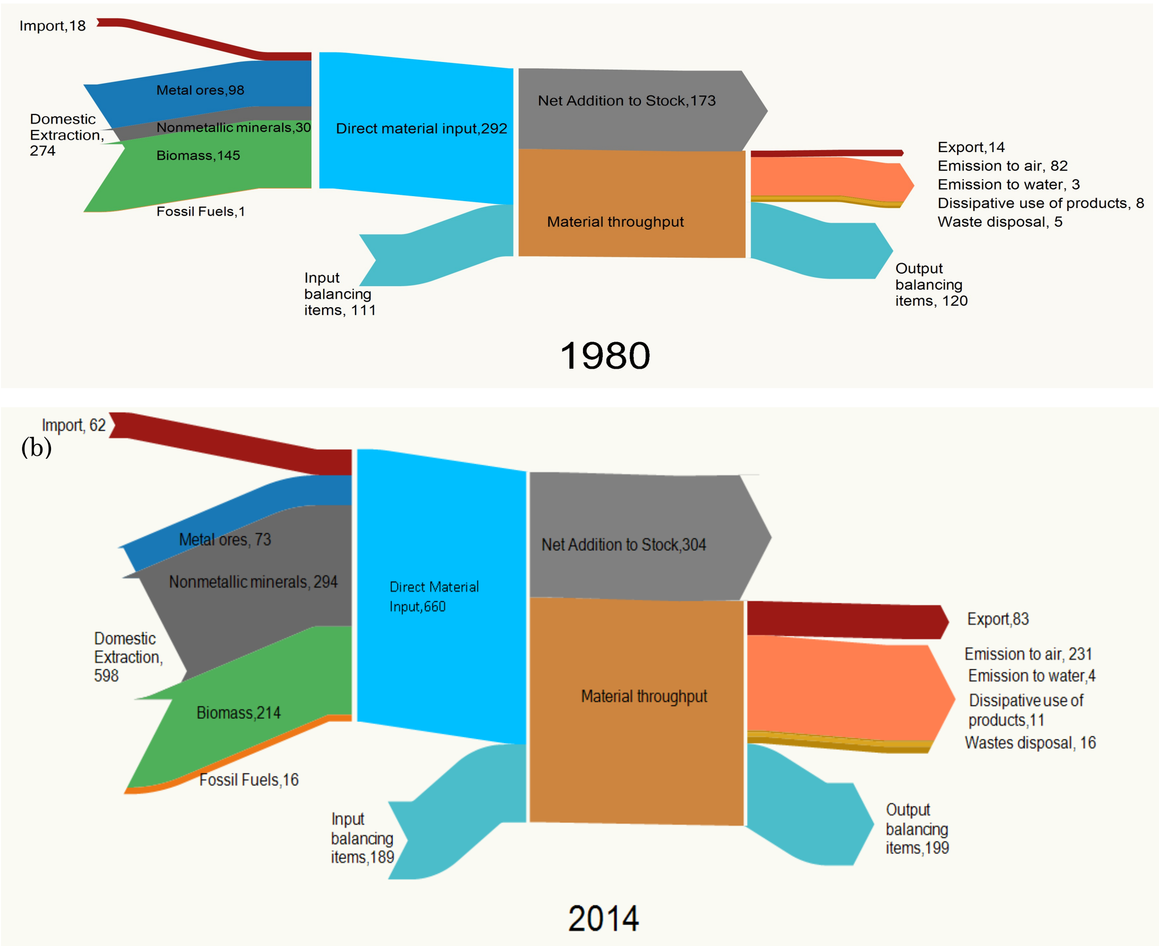


Figure 18. The extensive view of socio-economic metabolism of Philippines in (a) 1980 and (b) 2014.

Note: Notes: Unit- Million tonnes (Mt). Numbers may not sum to total due to rounding.

The material flow of the Philippines depicts trends and changes of an economy transitioning from agriculture-based to industry-based. The dominance of the services sector and less material-intensive economic activities has kept the growth of material consumption at bay. Direct material input doubled from 293 Mt in 1980 to 661 Mt in 2014, with imports as the greatest increase by 3.4 times. The outflow of materials likewise increased twofold from 110 Mt in 1980 to 344 Mt in 2014, with exports as the highest increase by sixfold. The accounts show steady yet minimal growth on the socio-economic metabolism of the Philippines. Despite the society's increasing material demands, the domestic environment still substantially supplies the material requirements of the Philippines, with a slight decline from 94% in 1980 to 90% in 2014.

While the amount of compounds and materials released back to the environment (DPO) is lower than material inputs (DMI), its cumulative growth rate at 3% was higher than DMI at 2.4% throughout the study period. Among subcategories of DPO, waste disposal to land has the highest growth rate at 3.3%, signifying inadequate efforts and resulting in calls to action that much needs to be done to manage solid wastes in the country.

The contribution of the Philippines to global material requirements is increasing, and the country has been a net exporter of materials since 2011. Exports increased sixfold while imports grew threefold from 1980 to 2014. PTB decreased from 4 Mt in 1980 to –21Mt in 2014, with the negative sign indicating that exports are greater than imported materials.

Material consumption (DMC) and the materials retained or added as stock (NAS) to the socio-economic system also increased. DMC cumulatively increased at 2.2% annually, while NAS is catching up at a lower rate of 1.7%. NAS increased from 173 Mt in 1980 to 304 Mt in 2014.

With the fast-growing construction industry, socio-economic metabolism shifted from renewables (51%) in 1980 to a predominantly non-renewable resource base of 64% fossil fuels, metal ores and non-metallic minerals in 2014. This type of metabolic transition has been recognized before (Krausmann et al. 2008) and is related to fast economic development, especially between 2011 to 2014 with an average GDP growth rate of 6.7% (UNCTAD 2016). The Philippines joins other high population density developing countries in Asia and the Pacific (UNCTAD 2016; Krausmann, et al. 2008) such as Thailand (51.2% in 2005) and China (62.3%

in 2005) (Schandl and West 2010; UNEP 2011b) in having construction minerals as the dominant component of DMC.

5.1.1 Resources extraction per province in the Philippines

Domestic extraction shows relative resource endowment at the provincial level in the Philippines. Despite the tenfold increase of nonmetallic minerals extraction, biomass remains to be the widely produced materials. Of 80 provinces, only one, the province of Palawan, has substantial percentages of extracted materials from four major categories, namely biomass (14%), fossil fuel sources (22%), non-metallic minerals (12%) and metallic minerals (52%). Palawan is the only province with natural gas and crude oil production and is also one of the major producers of nickel and cobalt metal ores.

The extraction of resources is used as proxy for the availability and distribution of resources among the provinces. It also signifies the active economic sectors in the provinces such as agriculture and fisheries for biomass, mineral mining industry and oil and gas industry for fossil fuel sources such as natural gas and crude oil. The equality of such distribution throughout the country is calculated using the Gini coefficient and plotting a Lorenz curve (Figure 19).

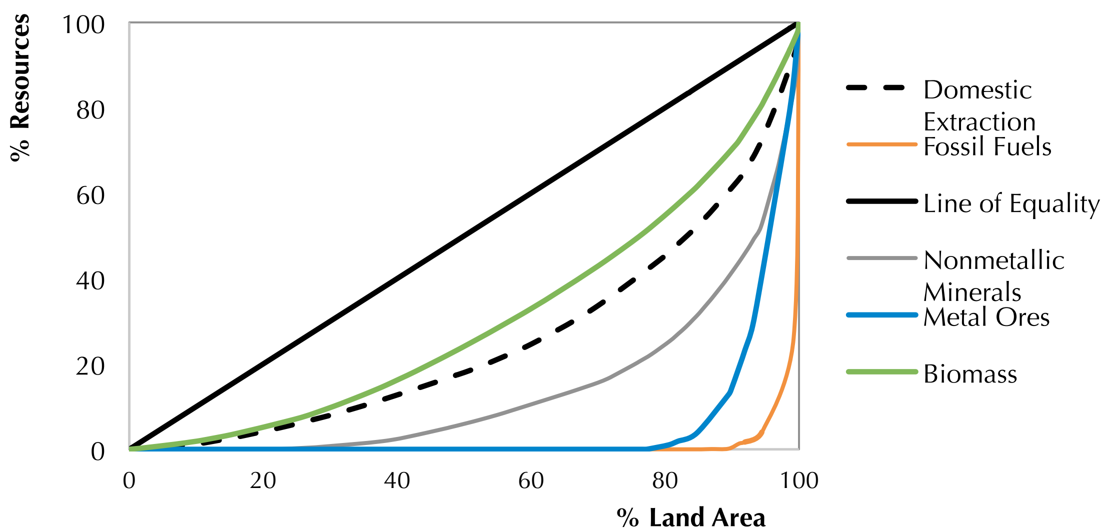


Figure 19. Lorenz curve of resource extraction of different material categories in the Philippines.

Substantial differences between main material categories are observed. The Lorenz curve and Gini coefficient show that biomass is the most equitably distributed material in the country, with a Gini coefficient of 0.2084, implying that all provinces are engaged in agriculture or fishery to various extents. Biomass also has the highest initial slope of its Lorenz curve, signifying the existence of socio-economic activities producing biomass-based materials such as agriculture and fishery industries at the provincial level for sustenance and livelihood. Agriculture and fishery provided 29% of employment in the country in 2015; however, it comprised a meager portion and decreasing share at 10% of GDP (PSA 2016).

Domestic extraction has a Gini coefficient of 0.3492, lying between biomass and non-metallic minerals (0.6480), suggesting the importance of these two material groups in society. Being an archipelagic country whereby transportation by water adds to the cost of materials, the supply of non-metallic minerals such as sand and gravel for construction should be taken from the source closest possible to construction sites. Also, cement production plants are constructed in the provinces with economically feasible limestone deposits. Thus, high quantities of non-metallic minerals are extracted in provinces close to or with cement production plants. On the other hand, metallic minerals are scarcely distributed in the Philippines, being extracted in 14 provinces. Similarly, fossil energy carriers comprised of natural gas, coal and crude oil are produced in only three provinces in the country.

Figure 20 shows the domestic extraction for each material category in the provinces of the Philippines in 2013. As flows cause environmental change (Eurostat 2001), the greater volume of domestic extraction entails higher pressure to the natural environment. The extraction of natural resources, such as mining of metallic ores and quarry of nonmetallic minerals pose pressure on the landscape and ecosystem. Based on this perspective, showing the map of domestic extraction per province provide the information on the material at which the provincial economy can capitalize to facilitate growth. At the same time, this DE account shows the intensity of pressure tantamount to carrying out the resource extractive industries in each province.

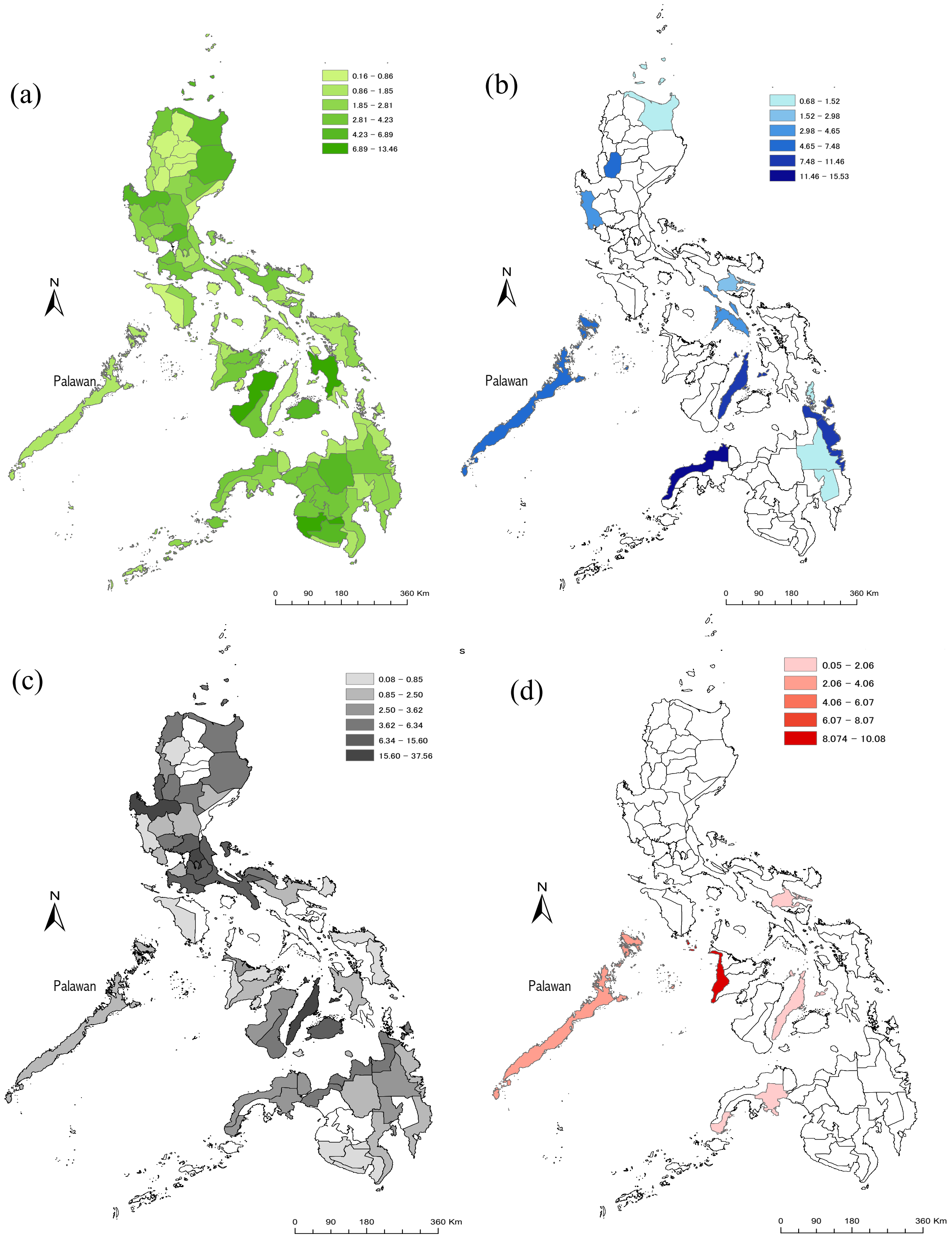


Figure 20. The Philippine map showing the domestic extraction per province in 2013 for (a) biomass; (b) metal ores; (c) nonmetallic minerals; and (d) fossil fuels. Range in million tonnes.

5.1.2 Per-capita metabolic rates

The DMC of the Philippines was 5.9 tonnes/capita in 2014 (Figure 21), fluctuating between 3.9 and 6.0 tonnes per capita over the past three decades. Although this material consumption is far below the average of 9.7 t/cap/a in 2010 in Asia

(Schaffartzik, et al. 2014), the shift from biomass (51% in 1980) to non-metallic minerals-based consumption (51% in 2014) shows that the transition from an agrarian towards an industrial metabolic profile is well underway, as manifest also in per-capita consumption in the Philippines. A similar trend was observed for other high-density developing countries such as China and Thailand at the start of the 1990s (UNEP 2011b) which demonstrates the Philippines' relative backwardness and the need to catch up with other Asian economies.

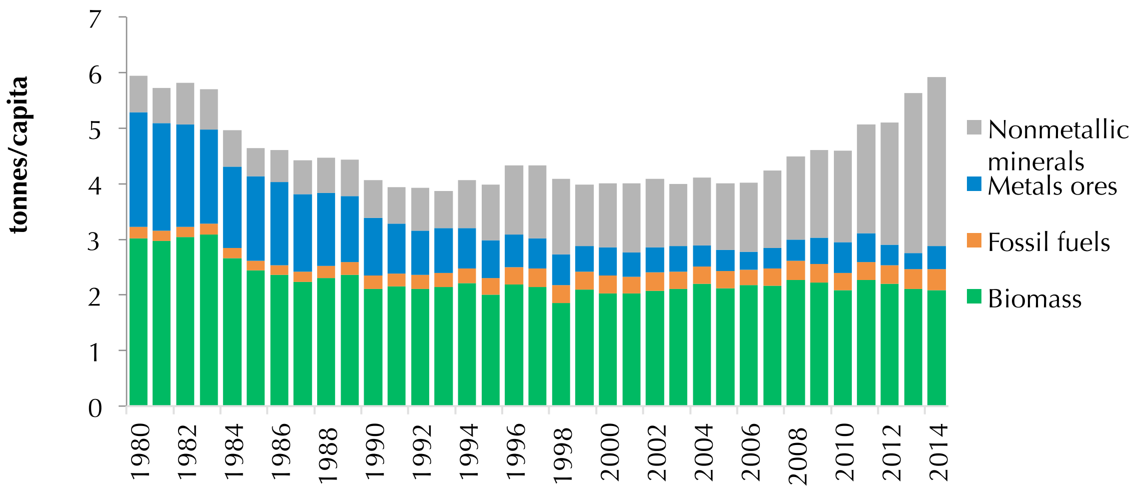


Figure 21. Metabolic rates (DMC) per main material category.

Despite undergoing industrialization, fossil fuel consumption in the Philippines grew minimally from 0.2 tonnes per capita (4%) in 1980 to 0.4 tonnes per capita (6%) in 2014 which is due to the still widespread consumption of fuel wood, used by 54% of households in 2011 (NSO 2011), as well as the considerable share of renewable energy sources such as geothermal energy that comprised 19% of the total energy supply mix in 2014 (PSA 2015).

Table 8 shows the comparison of DMC per capita of the Philippines with other Asian economies. Overall, the per-capita DMC trends recall Japan at the onset of its rapid economic growth prior to 1960 (Krausmann et al. 2011), China before 1985 (Schandl and West 2012), and similar to India's per capita DMC until a recent acceleration (Singh et al. 2012), indicating that the Philippines may be on the verge of rapid growth in material consumption as those countries have undergone, despite differences in other socio-economic.

Table 8. Comparison of DMC/capita with other Asian economies.

Selected Countries in Asia	Year	DMC tonnes/capita	GDP/capita US$ const 2005	Population Density
Philippines[1]	1980	6.0	1,109	159
	1985	3.34	912	182
	2010	4.24	1,403	312
	2014	5.90	1,665	334
China[2]	1978	3.23	192	109
	1985	4.34	342	112
	2008	17.05	2,416	142
India[3]	1994	3.3	442	350
	2008	4.3	869	395
Japan[4]	1958	4.2	7,079[5]	254[5]
	2005	13.1	35,781	337

Sources: [1]This study; [2]Schandl and West 2012; [3]Singh et al. 2012; [4]Krausmann et al. 2011; GDP/Capita (US$ const 2005) and Population Density from World Bank Indicators 2014. [5]1960

The share of metal ores in per-capita DMC gradually declined from 2 tonnes/capita in 1980 to around 0.4 tonnes per capita in 2014. The decline occurred when the mining industry slowed down in the 1990s. DMC/capita remained relatively stable thereafter, while the growing contribution of construction minerals is evident, having substantially increased since 2010.

As DMC suggests the waste potential of a society (EEA 2012; Giljum et al. 2014a), the transformation of material consumption in the Philippines from renewable (biomass) to nonrenewable-based materials (minerals and fossil fuels) signals changes in waste composition. The generation of environmentally friendly biodegradable waste (biomass) is now dominated by complex, hazardous and difficult to treat non-biodegradable wastes incurred from production and consumption of minerals and fossil fuels. Furthermore, finished products from minerals and fossil fuel entail disturbance to the natural environment through mining extraction and processing.

Per capita biomass consumption has been decreasing throughout the examined time period, implying an ongoing trend of lower reliance on renewable materials as the country advances. In contrast, per capita consumption of construction minerals has been increasing year on year both in share and absolute numbers, indicating that construction material consumption rates are increasing faster than population growth and showing the growing role of the construction industry in expanding the country's material stocks of buildings and infrastructures.

The per capita consumption of fossil energy carriers and ores and minerals remained mostly stable, together accounting for about 10% throughout, signifying that the increase of total consumption of these materials grows in unison with population. Metal ores and industrial minerals in the Philippines mostly end up as exports and compose a small fraction of DMC, yet it is interesting to note that the use of fossil energy carriers is remarkably stable, a very unusual trend for a dynamic and growing economy at this stage of development. Despite of the increasing demand for energy, the trend of fossil energy carrier consumption remained low, only reaching 0.40 tonnes per capita in 2014. This is attributed to the substantial contribution of renewable energy sources in the primary energy mix in the country. The Philippines is the second largest producer of geothermal energy (in absolute total number) for electricity production in the world, next to the United States (Friedleidsson and Omarsdottir 2013). In 2009, the non-fossil fuel sources of primary energy mix amounted to 42%, composed of geothermal (22.4%), hydro (6.15%), biomass (13.59%), wind/solar (0.01%) and biofuels (0.3%) (NEDA 2011). Fossil fuel production has been increasing with the recent development in the oil and gas industry in the country, but extraction is generally in proportion to the total demand. However, a tendency towards increasing fossil energy carriers in the country is not impossible since the country now focuses on developing more natural gas and oil fields, as well as growing coal production and consumption in the country.

MF/capita increased from 2.1 tonnes in 1990 to 3.9 tonnes in 2010, lower than DMC/capita with 4 tonnes in 1990 and 4.4 tonnes in 2010 (Figure 22). In comparison, MF is lower by 12% than DMC, a trend close to other developing countries such as Brazil (MF is 18% lower), Chile (75% lower) and China (15% lower) (Giljum et al. 2014b).

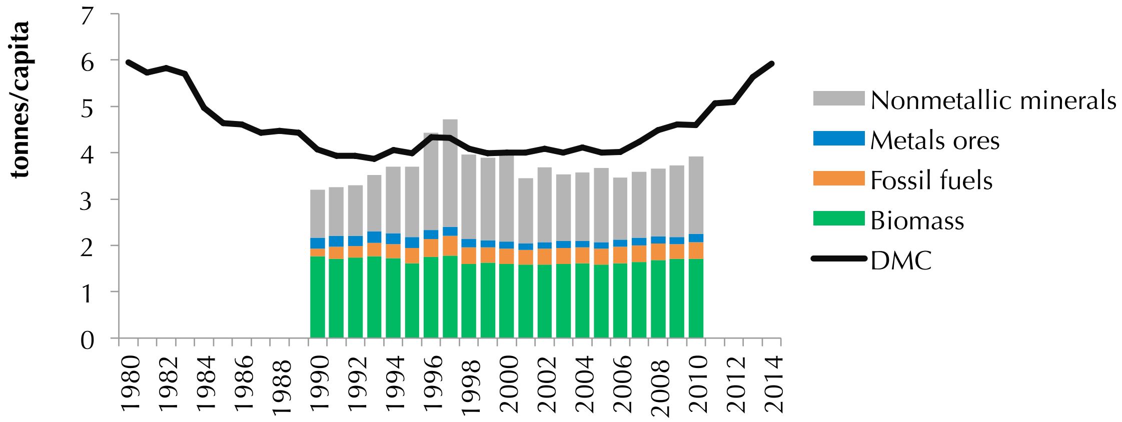


Figure 22. MF/capita (by main categories) and DMC/capita (total).

Most of the extracted metal ores are then exported to other countries for further processing into finished and usable products. Gross metal ores are accounted for in DE while exports account for metals and concentrates. Mine tailings remain in the socio-economic system and are accounted for in DMC. This discrepancy is taken into account in MF, which subtracts mine tailings and MF is thus lower than DMC. It implies that much of the primary production of material in the Philippines is for the benefit (or due to the demands) of other countries, which has economic and environmental consequences.

Production-based indicators such as DMC are moderately correlated with economic growth. On the other hand, a consumption-based indicator such as MF is highly related to economic growth and manifests the purchasing power of individuals in the country (Simas et al. 2017) which remains modest in the Philippines. This shows that despite the fact that the Philippines on average have very low DMC per capita, some material consumption occurs for consumers abroad (through exports) meaning materials available for domestic consumption and wellbeing are even lower, suggesting a low overall material standard of living.

5.2 Driving factors of material consumption

The 34-year period was divided based on the five transitions or changes in the country's political leadership. These different political administrations embodied various priorities implemented through the Medium Term Philippine Development

Plan. The driver on the changes in DMC per periods, are determined based on three factors namely; population, affluence, and technology or material intensity (Figure 23).

DMC, regarded environmental pressure, is influenced by economic and environmental policies. From one period to the next, population has decreased while affluence has increased its influence to the change of material consumption. From 1980 to 1998, population growth was the main driver of material consumption in the Philippines, with an annual population growth rate of 2.3%. The growth rate decreased to 2% per year from 2000 to 2007.

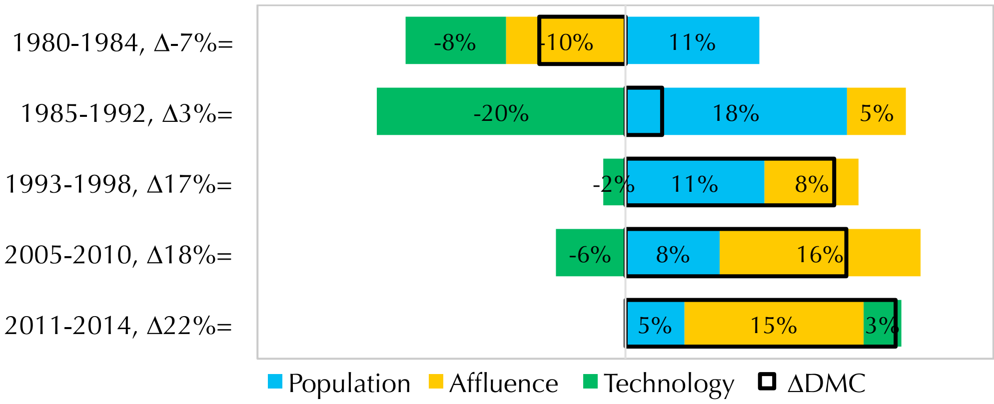


Figure 23. Drivers of domestic material consumption from 1980 to 2014.
Note: Impact (DMC); Driving Factors are Population, Affluence (GDP/Capita) and Technology (Material Intensity, DMC/GDP).

Affluence has become the major driver of material consumption in the latter decade of this study. Affluence grew in a steady yet slow rate throughout the 34-year period due to the effects of natural disasters, energy and political crises, as well as international global and financial crises. Despite an average growth factor of 3.4% during this period, the economic growth was hampered several domestic and international phenomena. The Asian Financial Crisis in 1997 and worsened by the effects of El Nino that resulted in a drop of GDP growth rates from 5.4% in 1997 to -0.3% in 1998 (PSY 2000); political crises in 2001 led to a growth rate of 1.76% and the Global Financial Crisis in 2008 decreased growth to only 0.92% in 2009. Nevertheless, the overall increase in material consumption driven by economic growth seems to indicate that the population is changing its lifestyles and consumption patterns.

Decreasing resource intensity (DMC/GDP) denotes increasing efficiency in the usage of the material, i.e. less material is required to produce a single unit of GDP. This factor has been negative in all periods except the first, acting as a moderating factor that counters the effects of P and A on the growth of consumption. Only in the 1999-2004 period it managed to counteract the growths of population and affluence, leading to a smaller growth rate of DMC compared to these two drivers. In the recent period most of these efficiency gains have been lost, as again DMC has been growing faster than population and affluence.

The latest period, 2011 to 2014 shows how affluence managed on driving the material consumption to increase at faster rate than any other periods. The population growth decreased continuously to 1.6% in 2014, thus its influence in the change of DMC. For such a short period of time, the DMC has changed by 22%, even the material intensity fell into positive side, showing the increasing material intensity in this period. Increasing material intensity is not a good indication, since it requires more materials to produce the same monetary unit, signifying that resource intensive economic activities are on the rise.

5.3 Monitoring decoupling of economic growth and environmental pressures

In an ideal world, the extraction, transformation, and subsequent consumption of natural resources should provide maximum economic gains with a minimum of disturbance to the natural environment and natural resource base. Because the extraction, processing, and utilization of natural resources have corresponding environmental burdens, changes reported in MFA indicators over time can be used as a proxy to monitor trends of environmental pressures in a country.

The Philippines has started to follow the material consumption pattern of the region with non-metallic minerals and fossil fuels as key material components of urbanization and industrialization. The transition from a biomass-based to a mineral-based economy that has taken place in the Asia and Pacific region since the 1970s (UNEP 2011a; Schandl and West 2010) manifested just recently in the Philippines' physical economy (Table 9).

Measuring material intensity using DMC as numerator shows a reduction from 5.4 kg per US$ in 1980 to 3.3 kg per US$ in 2010 and then increasing again to 3.6 kg per US$ in 2014. While material efficiency has improved over the past three decades it is still less than half of the global average. The material efficiency trend of production is close to that of consumption (MF/GDP) but at lower values of 3.2 kg per US$ in 1990 to 2.8 kg per US$ in 2010. The difference in material productivity depending on using DMC or MF as denominator is profound, with 0.186 US$ per kg in 1980 to 0.281 US$ per kg in 2014 (production-based) and 0.314 US$ per kg in 1980 to 0.360 US$ per kg (consumption-based).

Table 9. Key indicators of socio-economic and metabolic transition from 1980 to 2014.

Indicator	Unit	1980	1990	2000	2010	2014
Population density[a]	cap/km^2	159	208	261	312	334
Human Development Index[a]		0.561	0.586	0.610	0.649	0.668
Material use (DMC) per capita	t/cap/yr	6.0	4.1	4.0	4.6	5.9
Material footprint (MF) per capita	tonnes	-	3.2	4.0	3.9	-
Material intensity (DMC/GDP)	kg/US$	5.4	4.1	3.8	3.3	3.6
Material productivity (GDP/DMC)	US$/kg	0.186	0.246	0.266	0.307	0.281
Material productivity (GDP/MF)	US$/kg	-	0.314	0.264	0.360	-
Material load (DMC per unit area)	t/ha/yr	9.4	8.4	10.4	14.2	19.6
Share of biomass in DMC	t/yr	51%	52%	51%	45%	35%
Per capita CO_2 footprint[b]	tonnes	0.78	0.67	0.94	0.87	-

Sources: [a]United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition. [b]World Bank 2016

These improvements in the productivity (US$ per kg) of material use and consumption in the Philippines can be attributed to changes in economic structure. Replacing agriculture and industry which were the main economic activities in the 1980s, the service sector has emerged as a key contributor to GDP growth in the Philippines with over 50% since 2000. Services started to accelerate in the mid-

1990s when the Philippines started to receive high remittance inflows (12% of GDP in 2008). It is also driven by exports of services through the BPO industry (3.2% of GDP). High remittance inflows supported private consumption, thus compensating for stagnant investment in the country.

5.3.1 Economic growth and material use

Structural changes in the economy in the direction of services, which are less capital- and material-intensive, yielded a dividend of improved material efficiency. As a result, the relative changes in resource use and economic growth (Figure 24a) meant that MF and DMC grew more slowly than GDP, allowing increasing material productivity and relative decoupling to occur in the Philippines. Until 2010, material efficiency improved at an annual average rate of 1.7%. This trend has been reversed since 2010 when stronger growth in GDP required proportionally more materials, resulting in increasing material intensity of the economy, i.e. reduced material efficiency.

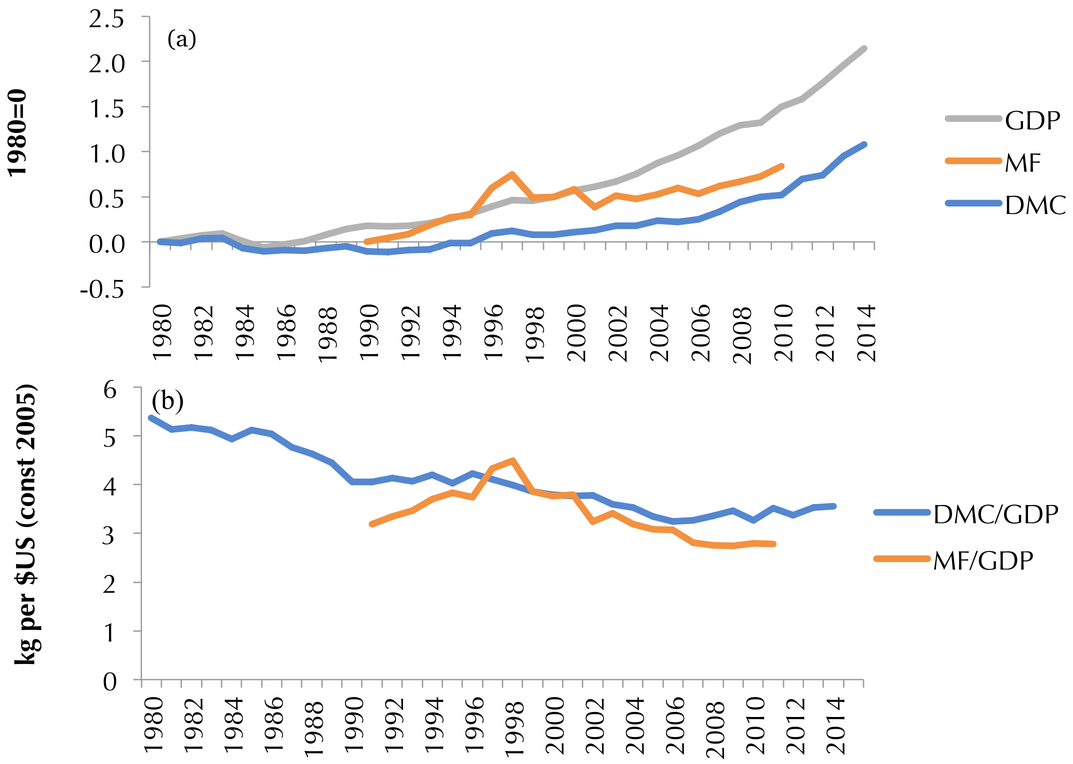


Figure 24. (a) Relative changes in economic growth and material use (DMC and MF); (b) Material intensity using production (DMC) and consumption (MF) based indicators.

Many high-income countries and mature economies have reduced their material intensity by externalizing resource-intensive processes to third countries (mainly in developing parts of the world), thereby stabilizing or even reducing their DMC leading to an apparent increase in material efficiency (Wiedmann et al. 2015; Gan et al. 2013). However, the trend in the Asia-Pacific region is one of increasing material intensity, influenced by China's resource-intensive economic growth and moving from traditional to modern technologies, processes and infrastructure that require more materials and energy (UNEP 2011b, 2013). Post-industrial economies are characterized by declining manufacturing and are largely sustained by service sector activities. A decrease in both the manufacturing and service sectors can severely inhibit the development of resource productivity (Gan et al. 2013). In the Philippines, however, the decline in manufacturing has been subdued by the increased share of services in GDP, allowing for improvements in material efficiency to some extent.

Despite increased total material consumption driven mainly by affluence (Martinico-Perez et al. 2016), low material intensity is observed in the Philippines. The economy managed to grow modestly, with material intensity declining by 1.1% annually from 1980 to 2014. This can be explained by the strong reliance on the services sector when it emerged as a key player in GDP growth since 2000. It accounts for 58% of GDP and provided 54% of employment in 2014. The GDP share of the services sector in the Philippines falls between the ASEAN countries (51%) and the world (66%) (UNCTAD 2016).

Technological change such as advancement in telecommunication allowed the service-type business process outsourcing industry in the Philippines to expand rapidly. On the same vein, improved technologies in energy sector promote energy efficiency and conservation strategies of the government such as energy labeling program for home appliances (DOE 2017). Efforts are also being undertaken to expand further the utilization of renewable energy sources, whereas of 2015, it supplies over a third of energy supply of the Philippines (PSA 2015).

With the services sector as the dominant contributor to GDP and technological innovations taking place, the Philippines is on track to achieve economic growth based on low material-intensive industries. However, with the country's aspiration for continued economic growth and improved quality of living, it is inevitable that material consumption will continuously increase at a faster rate in the Philippines.

5.3.1 Economic growth and output to environment

Figure 25 shows the year-on-year change of economic growth (GDP), output to environment (DPO), and addition to material stock (NAS) and resource productivity and efficiency. The economy, despite of modest growth at the onset of 1980, it surpassed the environmental pressure indicators from 2004 onwards. The figure also shows the output to environment used to increase at a higher rate than economic growth until 2005. Although such trend signals relative decoupling, the change has not slowed down nor stabilized yet, despite of the enacted environmental policies in the country. The NAS grew swiftly from 2010, as a result of active construction industry that increased consumption of nonmetallic minerals.

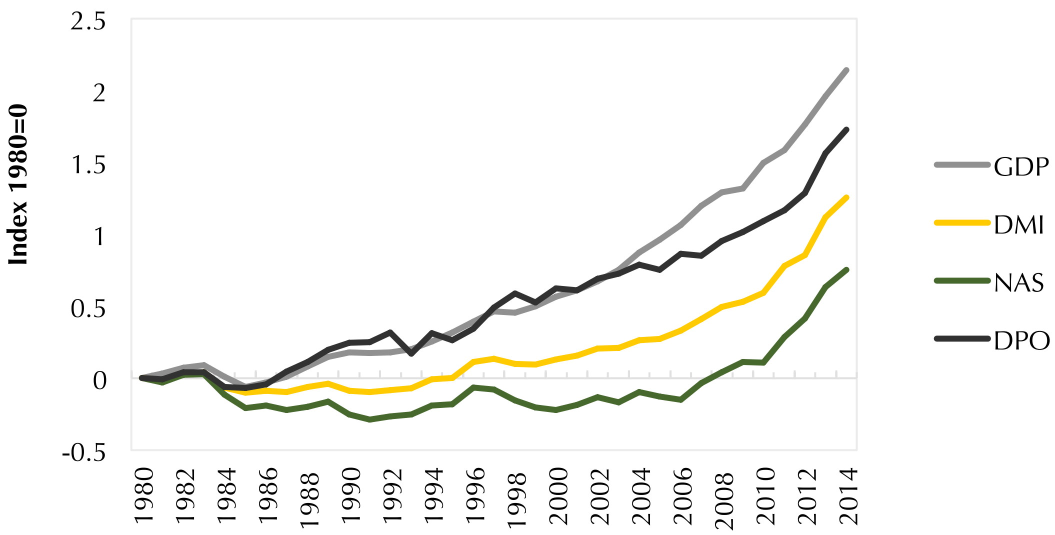


Figure 25. Relative changes in economic growth, material input (DMI) material output (DPO) and net addition to stock (NAS).

The relationship between per capita processed output (DPO) and the per capita affluence (GDP) in the Philippines is shown in Figure 26. The relationship that resembles the first half of the inverted "U" of the Environmental Kuznets Curve can be divided into two phases, a modest phase from 1980 to 2007 and a fast phase from 2007 onwards. The Philippines is still in the uphill side of the curve and it is unclear how long the rise will continue. What is clear from this analysis is that as the economy and affluence grow, environmental pressure, as shown by the amount of wastes material released to the domestic environment, is increasing.

High amounts of compounds emitted to air show that the atmosphere is the biggest dumping ground not only for industrial economies (Matthews et al. 2000) but also for emerging economies such as Philippines. This is despite of the implementation of policies to curb the air pollution in the country. The end-of-pipe approach being enforced to commercial and industrial plants to curb air pollution may have declined the emission for certain air pollutant, but it did not decrease the aggregate emissions to air. This increase can be attributed to the growing consumption and reliance to fossil energy carriers. The overall improvements to air emission and consumption of alternative energy sources from the policies promoting the utilization of biofuels (Biofuels Act of 2006) and renewable energy sources (Renewable Energy Act of 2008) have remained to be seen.

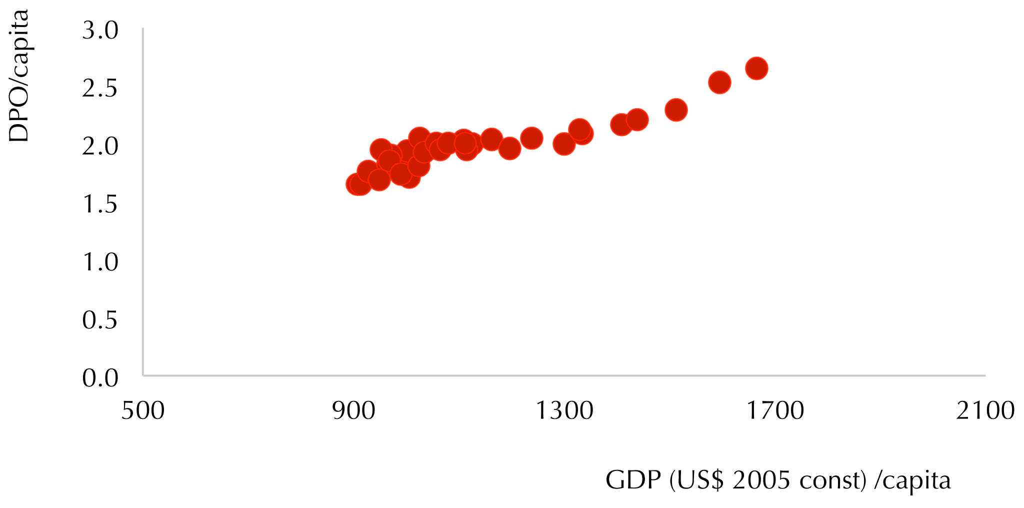


Figure 26. Environmental Kuznets curve of Philippines from 1980 to 2014.

The country's growing population, as well as increased economic activities, results in the increased solid waste generated in the country. Trends in waste reduction and increased recycling rates have been brought about by the implementation of the Solid Wastes Management Act of 2000. However, in the current phase, the country is far from stabilizing or declining its volume of solid waste generation. This is alarming, knowing that scarce land areas for human and economic activities have to be shared with the disposal of these solid wastes.

Being an agricultural country, with greater portion of population dependent on this sector, the salient environmental issues related to dissipative use of materials such as increasing consumption of dissipative fertilization and pesticides should not be neglected. Similarly, to increase fish catch entails higher fuel consumption for motorized fishing vessels. Measures have to be done to improve the efficiency and productivity in agriculture and fishery industries as well as to lessen the impacts of these activities to the natural environment.

The Philippines, as well as other developing nations, need not wait for these pressures to outweigh the benefits of economic growth and position the environment and greater population at stake. The Philippines needs to pass through the summit or bypass it with the use of green technology so economic development will not pose dangers to human and environmental health. Efforts must be exerted to improve and steer economic development towards a holistic approach that balances economic strategies with environmental protection.

5.4 Sustainability indicators from resource flow trends

Although the SDG indicators offer guidelines for all nations, the developing countries are still struggling to effectively implement and achieve these goals. Table 10 shows the aggregate indicators of material flows in the Philippines for the beginning year 1980 and the latest year 2014. It shows changes and trends in consumption and production indicators for SDG 8.4 and SDG 12.2, as well as support indicators to improve efficiency in resource consumption and production, keep track of the decoupling of economic growth from environmental degradation, and sustainable management and efficient use of natural resources.

Table 10. Aggregate indicators of material flow in the Philippines.

Indicator Class	Indicator	Unit	1980	2014
Extensive Indicators				
Input	DMI	Mt	293	661
Output	DPO	Mt	96	263
Consumption	MF	Mt	198[1]	364[2]
Production	DMC	Mt	278	577
Balance	NAS	Mt	173	304
	PTB	Mt	4	-21
Intensive Indicators				
Material Productivity	GDP/Input	US$/kg	0.18	0.25
	GDP/Consumption	US$/kg	0.31[1]	0.36[2]
	GDP/ Production	US$/kg	0.19	0.28
	GDP/Output	US$/kg	0.55	0.62
Material Efficiency/ Material Intensity	Input/GDP	kg/US$	5.57	4.00
	Consumption/GDP	kg/US$	3.19[1]	2.78[2]
	Production/GDP	kg/US$	5.40	3.60
	Output/GDP	kg/US$	1.83	1.59
Area intensity	DE/total land area	t/ha	9.40	19.60
		t/sq.km	799	1,742
Domestic resource dependency	DE/DMC	Ratio	0.99	1.04
Trade Intensity	Import to DMC	%	6.59	10.78
	Export to DMC	%	5.06	14.41

[1]1990; [2]2010.

Abbreviation: DMI-Direct material input; DPO-domestic processed output; MF-material footprint; DMC-Domestic material consumption; NAS-Net addition to stock; PTB-Physical trade balance; GDP-Gross domestic product (US$, constant 2005); DE-domestic extraction.

Area intensity has doubled indicating an increased amount of extraction. The area intensity of the Philippines grew from 799 tonnes per square kilometer (t/sq.km) to 1,742 t/sq.km. This value is lower than China (2,396.13 t/sq.km) but higher than Indonesia (1,035.62 t/sq.km), Japan (1,500.2 t/sq.km), and 4 times that of the world's average at 521.56 (UNEP 2016; Dai and Wang 2017). The area intensity in the country can be further elucidated using the presented accounts of DE per provinces. Extraction of natural resources through mining and quarrying as well as expansion of agricultural land to improve harvests alters land use. Such changes displace not only the people but as well as the flora and fauna thriving in the natural environment. Increased agricultural production necessitates more use of farm inputs such as fertilizers and pesticides that are often left unmanaged leading to eutrophication of adjacent bodies of water. With the current efforts of the government to decentralize economic growth, new buildings and transportation-related infrastructure are more likely to grow across the country. These pose both economic gains and challenges to the natural environment in the countryside. The accelerating development of physical infrastructure will increase extraction of materials and will soon conflict against the traditional use of land. Conversion from forestlands to agriculture, residential and commercial usage is inevitable. The demand for energy will further increase with industrialization, thus, emissions to air will continuously rise should the supply be taken from fossil energy carriers. These trends call for the attention of economic sectors, such as manufacturing industries to improve energy efficiency and overall material productivity; for construction sector improve of the quality of infrastructures; as well as the household level to practice proper segregation and disposal of wastes.

The aim of transitioning to a sustainable lifestyle and resource consumption in the Philippines has social complexity (Retamal and Schandl 2017). While material use and waste levels are still low in the Philippines, they will increase in future to build infrastructure and to fuel a growing economy. A focus on resource efficiency and greenhouse gas abatement will be an economically attractive option to drive innovation and development outcomes. According to policy makers in the Philippines, the most recent Development Plan for 2017 to 2022 is focus on providing foundation for sustainable development through focus on peace, security and safety, infrastructure development, and a healthy environment. The plan is anchored in the long-term vision to become a prosperous middle-class society in 2040 (AmBisyon 2040) (NEDA 2017).

Consumption and production indicators signify the increasing material requirements of the country as well as potential waste generation. The industrial based society would eventually shift waste composition from biodegradable to non-biodegradable materials like metals and non-metallic minerals. Disposal of these materials poses challenges in terms of quantity, handling and treatment. While this is not yet observed in the Philippines, since materials consumed are released to the environment at a faster rate (DPO>NAS) rather than having longer utility in the society, the future disposal of these materials should be taken into consideration. Increased output to the environment signifies inefficient allocation and use of resources that in turn makes consumption and production unsustainable. This trend highlights the need to work towards material recycling, as well as reformed governance and institutional structures that can support green growth and sustainable consumption and production.

Understanding these trends that represent the physical economy of the country and the movement of materials to and from and socio-economic systems would facilitate assessment and implementation of policies that could lead to curbing its impacts to the environment. The aggregate resource consumption of the Philippines may be well below than that of developing countries in Asia and Pacific (UNEP 2015; Dong et al. 2017) and has kept the resource consumption at modest growth, but by expounding the material flow accounts, it puts forward the encompassing issues between socio-economic and environmental systems. The indicators derived from material flow accounts can be related to societal planning, environmental planning and strategy. These activities drive the flow, technological aspects, how they are shaped and limited by their physical, economic, social and institutional frameworks. High-level policy framework in the Philippines should be put in place, with emphasis on improving resource efficiency through producing value-added materials and products. A policy framework is necessary to guide investment on green industry sectors, promote efficiency in industrial sectors, construction, such that the sustainable consumption and production be embedded in all economic activities. It is also deemed necessary to improve the recycling system, strict implementation and enforcement of policies related to solid wastes management, mitigating and regulating air emission, and wastewater.

6. Policy Implications

The environmental impacts per unit of materials has not been fully quantified, nevertheless, their disturbance potential tends to increase with the amount of materials utilized (EEA 1999; UNEP 2002; IPCC 2007). The increasing trend of domestic extraction of natural resources and the shift from renewable to non-renewable materials will lead to larger potential impacts of socio-economic activities on the Philippines environment.

Monitoring physical accounts of economic growth provides proxies for the material requirements of production, material standards of living and environmental impacts across the board. The indicators established in this study monitor the environmental effects of economic development. They also allow for progress to be monitored against the environmental goals and targets of the new SDGs and for specific targets to be set for the Philippines.

SDG target 8.4 calls for improved resource efficiency of production and consumption. Measured as material efficiency using DMC/GDP (material efficiency of production) and MF/GDP (material efficiency of consumption) we see the Philippines economy improving efficiency by an annual average of 1.7% and 0.7% respectively, during the period from 1990 to 2010. This suggests a yearly improvement in material efficiency of consumption for the Philippines economy of 1.2% to be a realistic, albeit not ambitious, target. This is a conservative assumption based on a target to improve per-capita income in 2040 to thrice the current (2015) level (NEDA 2017).

SDG target 12.2 requires sustainable material management and can be monitored using DMC per capita and MF per capita. Both values are comparatively low and well below the world average of 10 tonnes per capita. This suggests that future material requirements for the Philippines economy to build adequate infrastructure to fuel manufacturing industries and service consumption may well grow, perhaps even double, in the decades to come. This will require well-designed policy frameworks to mitigate the environmental impacts and social and health costs of such growth.

One important aspect of growing material use is the change in the quality and quantity of waste flows, as targeted by SDG 12.5. DMC per hectare of domestic area is a good first proxy for the development of the waste potential in the Philippines, since every material input, in the long run, turns into an emission or waste.

While MF is the consumption indicator that allocates used raw materials to domestic final demand (Weidmann et al. 2015), DMC is the appropriate indicator to measure potential domestic environmental pressure, given that it covers all material flows going into the socio-economic system that will be eventually released back to the environment in various forms such as solid waste, waste water, and air emissions (Giljum et al. 2014a; Eurostat 2001).

Increasing resource-extractive industries to promote economic growth will hasten the depletion of already-stretched resources in the Philippines. The current contributions of the services sector both to GDP (58%) and employment (54%) provides an opportunity for policies to focus and engage further in initiatives to sustain economic growth. Because of the sector's low resource-intensive nature, it would minimize the extraction of natural resources while focusing on improving human capital in the country. Beyond standard economic growth accounting, services-led industrialization may minimize the natural resource-based path of development. Unlike heavy industries that have potential polluting impacts, the services sector is more environmentally friendly. The proliferation of the mining industry should be geared towards value-added mineral production in the country.

Furthermore, this study supports the notion that the Philippines should take advantage of its human capital by strengthening its workforce through education, infrastructure, and good governance. The Philippines has young population and its service sector is the strongest and fastest growing sector dominating its contribution to GDP. It also provides the majority of employment in the country, usually from small to medium enterprises engaged in community and social services. Sustaining its growth and competitiveness is important; this will involve upgrading the service sector through enabling higher-end knowledge process outsourcing and higher value-added activities. This can be achieved through upgrading the educational system, and providing good infrastructure that will promote accessibility, mobility and connectivity.

The Philippines may have a low material standard of living currently but it is expected to increase as the country gears towards more an active construction industry that will enhance connectivity and mobility, provide employment, and boost economic growth. Establishing infrastructure would demand materials but in the long run, when properly in place, this would increase labor productivity in the service sector. These findings challenge the Philippines' capacity to simultaneously address the need for human development while minimizing impacts on the natural environment, thereby achieving the SDG targets. There is indeed ample room for further growth to improve economic productivity vis-à-vis the material productivity of the services sector in the Philippines.

Moreover, the information gathered from the domestic extraction at per provincial level could be utilized as the proxy on the about the resources available, active industrial sector and main economic activities in the locality. Such information could be utilized in the policy formulation and assessment towards sustainable resource management and economic growth in the provinces and regions.

7. Conclusion

7.1 Summary and discussion of findings

This study is the first attempt to present the full economy-wide material flow accounts for a developing country in Southeast Asia, the Philippines. It provides information on trends and changes in resource inputs, consumption and outputs to the environment. This research contributes in expanding the available literatures on trends of material flow accounts and analysis in the developing countries.

The socio-economic metabolism of the Philippines shifted from a renewable material based to a non-renewable material-based economy, heavily influenced by the growing consumption of construction minerals in the last five years. The Philippines as a high-density developing country shows a metabolic pattern that is distinctive to developing countries that mostly consume biomass and non-metallic minerals (Giljum 2010). With the increasing demand of construction minerals, the Philippines is inclined towards a non-renewable material-based economy, ending the historical dominance of renewable materials. As an emerging economy in its region, the Philippines is still at the starting point of rapid expansion in infrastructure, thus the continuous increase in consumption of construction minerals is inevitable. Growth in the consumption of fossil energy carriers has been remarkably modest due to the Philippines' geothermal energy production. The Gini coefficients of each material category reveal that despite of increased extraction of nonmetallic minerals, biomass is still the most widely distributed and extracted material per province in the country.

The country also shifted from being net resource dependent in 1980 to being a net resource provider in 2014, as shown by negative PTB due to the increased export of metal ores.

The lower MF (consumption indicator) than DMC (production indicator) suggests that the average amount of materials embodied in imports is lower than the average amount of materials embodied in exports. This indicates that processed goods in exports dominate trade in the Philippines, which has both economic and environmental consequences. The environmental pressures related to the resource-extractive industry and material exports should be accounted for not only in the Philippines but also in countries importing these materials.

The growing affluence has overtaken population growth as the major driver of resource consumption, calling for increased focus on sustainable economic growth in policy. Specifically, the improving average affluence in the country does not necessarily manifest itself in equal distribution of the consumption of these materials, which must be addressed, and sectors that are not resource-intensive such as tourism should be strengthened. At this point in time the country's per-capita DMC levels are similar to those that other East Asian and South Asian countries - namely Japan, China, and India - had on the verge of their growth surge phases. The Philippines might already be on a course to follow these countries' trends in upcoming years and the current period may be the calm before the storm, so to speak - a window of opportunity to plan a more resource-efficient growth strategy.

The Philippine economy managed to grow with less material intensity because of the increasing share of the services sector in economic growth. Relative changes in resource use expressed as DMC and MF grew in unison but at a lower rate than that of GDP, signifying relative decoupling of material consumption and economic growth in the Philippines. The relative change of the output to environment (DPO) used to increase at a higher rate than economic growth until 2005. Such improvement signals relative decoupling but its does not mean an overall reduction of DPO since the environmental Kuznets curve shows growing pressure on the environment as the economy grows. DPO has kept on increasing despite of the enacted environmental policies in the country.

The trends in resource inputs and outputs provide a dashboard of indicators on sustainable resource management that will provide policy insights towards achieving SD goals 8.4, 12.2 and 12.5. The information on material use and material efficiency are contextualized by an analysis of current policy that addresses either the broader development agenda of the country, sector-specific policies, or policies that explicitly aim for SCP, investment in a green economy and resource efficiency. It is perhaps too early to see a signal of policy efforts in the material flows of the Philippines as much of the observed change has been driven by an expansion in population, increasing urbanization trends and a growing economy. In the context of the SDGs it will be of great importance, however, that overall environmental pressure related to human development goals is monitored and that the Philippines develops targets for material consumption and waste reduction that are both realistic and ambitious. Based on the analysis provided in this research we aim to suggest targets for improvements in material efficiency and per-capita material use.

7.2 Overall achievement of the research objectives

This study provides an empirical account of the Philippines' resource consumption and economic growth, and thus clarifies past trends in the physical dimensions of economic growth in the country. This study contributes to the body of knowledge of industrial ecology and socio-economic metabolism as it contributes in enriching the available literatures on trends of material flow accounts and analysis in the emerging economies. Moreover, it fills the gaps that existed in the previous studies and provided longer compilation of material flow accounts of the Philippines by utilizing country-based estimation parameters and primary sources of statistical data, and thus enabled a deeper insight into the trends and drivers of material consumption and policy implications.

The full material flow account creates an opportunity to identify flows carrying harmful materials, and their origin and fate in the socio-economic and environmental system. It also pinpoints the economic sectors and activities responsible for these flows, thereby providing guidance on developing interventions towards achieving sustainability in resource management. This study is relevant and timely, as the Philippines is putting policy priority on tackling issues of poverty, population growth, economic development, and the environment. These priorities and challenges are also being tackled by other developing countries in Southeast Asia and the rest of the world.

To summarize the achievements of this study, the following revisits the objectives of this study to address the main question, "What are the trends of material flow in the emerging economy such as the Philippines?"

1. Develop the full economy-wide material flow account of the Philippines

Adapting the Eurostat methodological guide to Philippines' material-based, thereby utilizing primary sources of statistical data and country-based estimation parameters developed the material flow account from 1980 to 2014. As the resource input increased by twofold, the output to the environment has tripled after 34-year period. The net addition to stock of materials in the socio-economic systems has been shown to be of slower rate than the waste and emissions to the environment. This indicates the lack of infrastructure investments for a modestly growing economy such as Philippines.

2. Elucidate the domestic extraction per province in the Philippines

Philippines, as an archipelagic country, the natural resources are neither equally distributed nor available to each island and province. Thus, elucidating further the material flow for in different spatial area in the country could provide information about the resources available, active industrial sector and main economic activities in the area. The first ever-domestic extraction account of 80 provinces in the Philippines was developed. It attunes the regions and provinces in developing their own material flow accounts that could be utilized in the policy formulation and assessment in the local government units. Almost all provinces are engaged in biomass extraction, while 79% are extracting non-metallic minerals, 18% are involved in mining of metal ores, and 4% are into producing fuel energy sources such as oil and gas, and coal extraction. Furthermore, DE account shows the intensity of pressure tantamount to carrying out the resource extractive industries in each province. Taking DE as proxy for environmental pressure, this information provides caution to the local policy makers that the greater volume of domestic extraction entails higher pressure to the natural environment. Resource extractive economic activities should be accompanied with utmost diligence to avoid irreversible damage to the natural environment of the islands and provinces.

3. Identify the drivers of changes in material consumption

The growing affluence has overtaken population growth as the major driver of resource consumption, calling for increased focus on sustainable economic growth in policy. Specifically, the improving average affluence in the country does not necessarily manifest itself in equal distribution of the consumption of these materials, which must be addressed, and sectors that are not resource-intensive such as tourism should be strengthened. At this point in time the country's per-capita DMC levels are similar to those that other East Asian and South Asian countries - namely Japan, China, and India - had on the verge of their growth surge phases.

4. Monitor progress of decoupling of economic growth and material use

The Philippine economy managed to grow with less material intensity because of the increasing share of the services sector in economic growth. Relative changes in resource use expressed as DMC and MF grew in unison but at a lower rate than that of GDP, signifying relative decoupling of material consumption and economic growth in the Philippines. On the same vein, the output to the environment has seen initially to change faster than GDP until 2005. The DPO increasing at a lower rate supports relative decoupling of economic growth and material use. Although this relative decoupling does not mean reduction of DPO since the environmental Kuznets curve shows the growing pressure on the environment as the economy grows. Indicators of material flow accounts serve as proxy indicators of environmental pressures tantamount to growing economic activities in the Philippines.

5. Determine the relationship of material flow with the economic development plans and policies.

The economic structure changed from the dominance of agriculture and industry activities in the 1980s to service sector as the key contributor to GDP growth in the Philippines with over 50% since 2000. Such changes improved the productivity and efficiency of material use and consumption in the Philippines. Economic and environmental policies have affected the trends of socio-economic metabolism in the country. The energy policies encourage tapping and expanding on the use of indigenous and renewable energy resources such as geothermal, hydroelectricity, and biomass. This resulted to the minimal increase in the per capita fossil fuel consumption despite of the active economic growth. Economic policies also resulted to the expansion of exports of services such as business process outsourcing (BPO) industry. Although to expand and improve the quality of services, support physical infrastructure has been constructed resulting to the increased consumption of non-metallic minerals. This has changed the material-based of the Philippines from biomass or renewable to minerals and fossil fuels or non-renewable based society.

Policy changes, trade liberalization and globalization, as well as a promising workforce, have changed the path towards services-led industrialization in the Philippines. This study suggests the extent to which the present resource consumption patterns can be improved. Specifically, it points out specific sectors to focus on, such as the services sector, and materials producing high value product from metal ores, to assist growth patterns in the Philippines to traverse towards sustainable consumption and production.

The information on material use and material efficiency are contextualized by an analysis of current policy that addresses either the broader development agenda of the country, sector-specific policies, or policies that explicitly aim for SCP, investment in a green economy and resource efficiency. It is perhaps too early to see a signal of policy efforts in the material flows of the Philippines as much of the observed change has been driven by an expansion in population, increasing urbanization trends and a growing economy. In the context of the SDGs it will be of great importance, however, that overall environmental pressure related to human development goals is monitored and that the Philippines develops targets for material consumption and waste reduction that are both realistic and ambitious. Based on the analysis provided in this research we aim to suggest targets for improvements in material efficiency and per-capita material use.

In comparison to the well-studied BRICS developing countries, which are arguably stand-alone cases due to their size and characteristics, the fact that the Philippines is "only" a medium-sized country with an emerging economy places it in a sizable group of countries which face similar socio-economic and environmental challenges. The ongoing patterns of economic globalization and their effects on economic development, such as long-term shifts in import and export trends and related material footprints, remittances from Filipinos working abroad, and changes in the contribution of economic factors, all appear to various extents in the rest of the ASEAN countries and other developing nations in Asia, the Pacific, and beyond. In all such countries, the growing awareness and calls for action exemplified in the SDGs need be addressed by well-designed policies and will require monitoring and evaluation capacity as proposed here.

7.3 Limitations of the study

The full economy-wide material flow account of the Philippines has been mainly developed based on the national statistics data. Domestic unused extraction or the unused materials accompanying the raw material extraction are not considered in this study. These materials, also termed as 'hidden flows' or 'ecological rucksacks' are comprised of overburden or top soil from mining, soil excavation during construction, gas flared in oil and gas extraction, unused byproducts from agricultural harvests, felling of trees and other similar activities.

Also, the compilation of the net addition to stock utilized the indirect estimation method. The domestic extraction per province was accounted for 2013 only since it is the latest published available data. The focus was on the DE only and not on the material consumption since the import and export data for each province must be clearly delineated, thus, data as such is not yet available.

7.4 Areas for further research

As the first attempt to develop the full economy-wide material flow accounts of the Philippines, this research field is still at the early stage and has evolving slowly in the country. The study covers only the 34-year period of economic growth and material consumption in the Philippines, thus can be extended and updated based on the available data.

The country has entered the period of 'Golden Age of Infrastructure' from the onset of 2016. The "Build Build Build" program is embodied in the Philippine Development Plan from 2016-2022. Such active economic activities can be considered as "exciting years" in terms of material stocks and flow in the Philippines, thus offers a lot of researchable topic in the field of socio-economic metabolism and industrial ecology. Further research focusing on the material stock and material intensity of stocks in the Philippines could provide additional perspective and additional contribution to material stock research in socio-economic metabolism. This study utilized the indirect method to estimate the net addition to stock. It is recommended to utilize the recent and available methods on direct estimation of NAS.

Looking further into the material flow accounts at different spatial levels in the Philippines could provide further perspective in the material flow accounts of small islands. Such information can also be utilized in the policy assessment and formulation in the local government units.

Further, accounting the recycling of resources per industry sector or at material level in the Philippines has to be focused on in the future studies.

Notes:

Substantial fraction of this dissertation was peer-reviewed and published (Martinico-Perez et al. 2017, 2018; Martinico-Perez et al. *In press*) as part of the PhD requirements.

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List of Tables

LIST OF FIGURES

REFERENCES

Abrenica, J., Llanto G., 2003. Services. In: The Philippine Economy: Development, Policies, and Challenges. Edited by A Balisacan and H. Hill. Quezon City: Ateneo de Manila University Press.

ADB, 2003. Metro Manila Solid Waste Management Project (TA 3848- PHI). Final Report No. 5c –Study of Markets for Recycled Solid Waste. Asian Development Bank, Manila Philippines.

Adriaanse, A., S. Bringezu, A. Hammond, Y. Moriguchi, E. Rodenburg, D. Rogich, and H. Schutz. 1997. Resource Flows: The Material Basic of Industrial Economies. World Resource Institute.

Aldaba, R., 2014. The Philippine Manufacturing Industry Roadmap: Agenda for New Industrial Policy, High Productivity Jobs, and Inclusive Growth. Makati City, Philippines: Philippine Institute for Development Studies.

Amaya F.L., Gonzales T.A., Hernandez E.C., Luzano E.V., Mercado N.P., 2012. Estimating Point and Non-Point Sources of Pollution in Binan River Basin, the Philippines. APCBEE Procedia (1) 233–238.

Ayres, R. U. and U. E. Simonis, eds. 1994. Industrial metabolism: Restructuring for sustainable development. New York: United Nations University Press.

Ayres, R. U. 1989. Industrial metabolism. In Technology and environment, edited by J. H. Ausukl and H. E. Sladovich. Washington, D.C.: National Academy Press, pp. 2349.

Allesch A. and P. Brunner, 2017. Material Flow Analysis as a Tool to improve Waste Management Systems: The Case of Austria. Environmental Science and Technology, 51, 540-551.

Baconawa, E.T. 1986. Prospects for Reconversion of Sugarcane into Animal Feeds in the Philippines. http://www.fao.org/docrep/003/s8850e/s8850e08.htm. Accessed on February 2014.

Baconguis, R. S. 2007. Abandoned Biomass Resource Statistics in the Philippines. http://www.nscb.gov.ph/ncs/10thNCS/papers/invited%20papers/ips-20/ips20-03.pdf. Accessed on June 2014.

Barbiero, G., S, Camponeschi, A. Femia, G. Greca, A. Macrì, A. Tudini, and M. Vannozzi. 2003.1980-1998 Material-Input-Based Indicators Time Series and 1997 Material Balance of the Italian Economy. ISTAT, Rome.

Brahim S.P., 2014. Renewable energy and energy security in the Philippines. Energy Procedia (52) 480 – 486.

Behrens, A., Giljum S., Kovanda J., Niza S., 2007. The material basis of the global economy Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies. Ecological Economics 64: 444-453.

BFAR, 2009. Seaweed Farming. Office Report, Aquaculture Unit, Camarines Sur: Bureau of Fisheries and Aquatic Resources, 2 9.

Briones, R., Quimba F., Bungcayao, J., Paglingayen J., Libunao I., 2011. Assessing Development Strategies to Achieve the MDGs in the Republic of Philippines. Country Study, Realizing the Millennium Development Goals through socially inclusive macroeconomic policies Project, Manila, Philippines: United Nations Department for Social and Economic Affairs.

Bringezu, S., H. Schutz, and S. Moll. 2003. Rationale for the Interpretation of Economy-wide Materials Flow Analysis and Derived Indicators. Journal of Industrial Ecology. Pp. 43 – 64.

Bruckner, M., Giljum, S., Lutz, C., Wiebe, K. S., 2011. Materials embodied in international trade - Global material extraction and consumption between 1995 to 2005. Global Environmental Change 22: 568-576.

Bureau of Fisheries and Aquatic Resources. 1990-2010. Philippine Fisheries Profile. Quezon City, Philippines.

Cabalu H., Koshy P., E. Corong, Rodriguez U.P., Endriga B., 2015. Modelling the impact of energy policies on the Philippine economy: Carbon tax, energy efficiency, and changes in energy mix. Economic Analysis and Policy (48) 222-237

Canlas, D., Nimura Y., 2001. Socio-Economic Reform Program in the Philippines: Impacts and New Directions. Edited by D. Canlas and Y. Nimura. Institute of Developing Economies.

Chiu, A.S.F., Dong, L., Geng, Y., Rapera, C., and Tan, E., 2017. Philippine resource efficiency in Asian context: Status, trends and driving forces of Philippine material flows from 1980 to 2008. Journal of Cleaner Production 153(1), 63-73.

CeMAP 2015. 2015 Annual Cement Industry Report. Cement Manufacturer's Association of the Philippines Inc. Makati City, Philippines

Chiu, A.S.F. 2011. Scoping Paper for Green Economy and SCP on the Philippines. http://grf-spc.weebly.com/uploads/2/1/3/3/21333498/grf-2012-rio-chiu.pdf. Accessed on June 2014.

Commoner, B. 1972. The Environmental Cost of Economic Growth. In Population, Resources and the Environment, edited by R. G. Ridker. Washington DC: U.S. Government Printing Office, pp. 339–363.

Dai T. and W. Wang 2017. The Characteristics and Trends of Socioeconomic Metabolism in China. DOI: 10.1111/jiec.12659

Dong L., M. Dai, H. Liang, N. Zhang, N. Mancheri, J. Ren, Y. Dou, and M. Hu. 2017. Material flows and resource productivity in China, South Korea and Japan from 1970 to 2008: A transitional perspective. Journal of Cleaner Production 141 (2017) 1164-1177

Dorfman, R., 1979. A formula for the Gini coefficient. Reviewof Economics and Statistics 61(1), 146–149.

DENR. 1994. National GHG Inventory: The Philippines Initial National Communication on Climate Change. Department of Environment and Natural Resources. Quezon City, Philippines.

DOE, 2017. Standards for Energy Efficiency Ratio and Labeling Requirements. Department of Energy. https://www.doe.gov.ph/standard-energy-efficiency-ratio-and-labeling-requirements. (Accessed on 22 November 2017)

DOE, 2012. Philippine Energy Plan 2012-2013. Department of Energy. Taguig City, Philippines.

DOE. 1996. Philippine Energy Plan 1996-2025. Department of Energy. Manila, Philippines.

DENR. 1990, 1995, 2000, 2005, 2010. Department of Environment and Natural Resources - Philippine Forest Statistics. Quezon City, Philippines.

EEA, 1999. Material Flow-based Indicators in Environmental Reporting. Spangenberg, J., A. Femia, F. Hinterberger, H. Schütz, S. Bringezu, C. Liedtke, S. Moll, F. Schmidt-Bleek. Luxembourg: European Environmental Agency.

EEA, 2012. Material Resources and Wastes - 2012 Update. Copenhagen, Denmark: European Environmental Agency.

EDGAR, 2018. Global CO_2 emissions from fossil fuel use and cement production 1970-2015. EDGARv4.3.2, European Commission, Joint Research Centre (JRC)/PBL Netherlands Environmental Assessment Agency. Emission Database for Global Atmospheric Research (EDGAR), release version 4.3.2. http://edgar.jrc.ec.europe.eu, 2016 forthcoming (accessed 12 February 2018)

Ehrlich, P. and J. Holdren. 1972. Impact of population growth. In Population, Resources, and the Environment, edited by R.G. Riker. Washington DC: U.S. Government Printing Office. pp. 365–377.

Eurostat. 2001. Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide. Luxembourg.

Eurostat. 2009. Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide. Luxembourg.

Eurostat. 2013. Economy-wide Material Flow Accounts (EW-MFA), Compilation Guide 2013, Luxembourg.
Eurostat, 2016. Economy-wide material flow accounts (EW-MFA) Manual 2016 Draft version on DPO and Balancing Items. Luxembourg: European Union.
Fischer-Kowalski, M., F. Krausmann, S. Giljum, S. Lutter, A. Mayer, S. Bringezu, Y. Moriguchi, H. Schütz, H. Schandl, and H. Weisz. 2011. Methodology and Indicators of Economy-wide Material Flow Accounting. Journal of Industrial Ecology 15(6): 855–876.
Fischer-Kowalski, M. 1998. Society's metabolism-the intellectual history of materials flow analysis. PartI: 1860-1970. Journal of Industrial Ecology 2(1):61-78
Fischer-Kowalski, M. and W. Hüttler. 1999. Society's metabolism. Journal of Industrial Ecology 2(4): 107–136.
Fischer-Kowalski, M. and H. Haberl. 1993. Metabolism and colonization. Modes of production and the physical exchange between societies and nature. Innovation in Social Science Research 6(4): 415442
FMB, 2016. Philippine Forest Statistics 2016. Department of Environment and Natural Resources, Forest Management Bureau. Quezon City, Philippines.
Food and Agriculture Organization of the United Nations. Statistics Division. (FAOSTAT). http://faostat3.fao.org/home/E. Accessed on January 2014.
Fong-Sam, Y., 2012. Minerals Yearbook: Philippines. 2010 Annual Report, Philippines: United States Geological Survey.
Foreign Trade Statistics of the Philippines, 1981, 1984, 1987, 1989, 1996, 1997, 1998, 2001, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014. National Statistics Office. Quezon City, Philippines.
Francisco R.V., 1996. Greenhouse gas inventory of he Philippines: Interim Report. In Greenhouse Gas Emission Inventories B.V. Vraatz et al. (eds). Kluwer Academic Publishers. Pp 189-199.
Fridleifsson, I. B. and M. Omarsdottir. 2013. Geothermal Energy in Developing Countries and the MDGs. http://unu.edu/publications/articles/geothermal-energy-in-developing-countries-and-the-mdgs.html. Accessed on May 2014.
Gan, Y., Zhang T., Liang, S., Zhao, Z., Li, N., 2013. How to Deal with Resource Productivity. Journal of Industrial Ecology 17 (3), 440-451.
Gierlinger, S. and F. Krausmann. 2012 or 2011(??). The Physical Economy of the United States of America. Journal of Industrial Ecology 16(3): 365–377.
Giljum, S., M. Dittrich, M. Lieber, and S. Lutter. 2014a. Global Patterns of Material Flows and their Socio-Economic and Enviromental Implication: A MFA Study on All Countries World-Wide from 1980 to 2009. Resources 3(1):319-339.
Giljum, S., Bruckner, M., Martinez, A., 2014b. Material Footprint Assessment in a Global Input-Output Framework. Journal of Industrial Ecology 19, (5): 792-804.
Giljum S., M. Dittrich, S. Bringezu, C. Polzin, and S. Lutter. 2010. Resource Use and Resource Productivity in Asia. Trends Over the Past 25 Years. SERI Working Paper No 11. Sustainable Europe Research Institute (SERI). Vienna, Austria.
Giljum, S. 2004. Trade, material flows and economic development in the South: The example of Chile. Journal of Industrial Ecology 8(1-2): 241-261.
Griggs, D., Stafford-Smith, M., Gaffney, O., Rockstrom, J., Ohman, M. C., P. Shyamsundar, Steffen W., Glaser, G., Kanie N., Noble I., 2013. Sustainable development goals for people and planet. Nature, 495, 305-307.
Haber H., Fischer-Kowalski, M., Krausmann, F., Weisz, H., Winiwarter, V., 2004. Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. Land Use Policy 21 (2004) 199–213
Habito, C. F. 1994. Kasarinlan, Vol 9 Nos. 2 & 3, 4th Quarter 1993 and 1st Quarter 1994
Hashimoto, S. Tanikawa, H. and Moriguchi, Y. (2009) Framework for estimating potential wastes and secondary resources accumulated within an economy: A case study of

construction minerals in Japan. Waste Management. Vol. 27, 2859–2866.
Hoekman P. and von Blottnitz Harro. 2016. Cape Town Metabolism: Insights from a Material Flow Analysis. Journal of Industrial Ecology. DOI: 10.1111/jiec.12508
Hotta, Y., 2011. Is Resource Efficiency a Solution for Sustainability Challenges? S.A.P.I.EN.S [Online], 4.2, Online since 09 September 2011, Connection on 10 October 2012. URL : http://sapiens.revues.org/1161
Hu. M, van der Voet, E., Huppes, G. (2010) Dynamic material flow analysis for strategic construction and demolition wastes in Beijing. Journal of Industrial Ecology. 51, 97 – 124.
Hubacek, K., D. Guan, and A. Barua. 2007. Changing lifestyles and consumption patterns in developing countries: A scenario analysis for China and India. Futures. Volume 39 (9), 1084 – 1096.
Infante-Amate J., Soto D., Aguilera E., Garcıa-Ruiz R., Guzman G., Cid A., Gonzalez de Molina M., 2015. The Spanish Transition to Industrial Metabolism Long-Term Material Flow Analysis (1860–2010). J. of Ind. Ecol. 19(5). pp. 866–876.
International Energy Agency (IEA). 1994-2010. World Energy Outlook. OECD/IEA. France.
International Monetary Fund (IMF). Philippines. http://www.imf.org/. Accessed on June 2014.
IPCC, 2006. Intergovernmental Panel for Climate Change. Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Japan.
IPCC, 2007. Climate change 2007:The Physical Science Basis. Summary for policy makers. Formally Approved at the 10th Session of Working Group I of the IPCC. Intergovernmental Panel on Climate Change, Paris.
IMF, 2015. World Economic Outlook:Uneven Growth-Short and Long-term Factor. International Monetary Fund. Washington (April).
Jurado, G., 2003. Growth Models, Development Planning, and Implementation in the Philippines. Philippine Journal of Development XXX, 55: 1-24.
Jegillos, S. R. 2000. Reducing the Impacts of Environmental Emergencies: The Case of the 1997-1998 El Nino Southern Oscillation. The Philippine Study. Asia Pacific Disaster Management Center, Inc (APDMC). Manila, Philippines.
Kastner, T. 2009. Trajectories in human domination of ecosystems: Human appropriation of net primary production in the Philippines during the 20th century. Ecological Economics 69(2). Special Section: Analyzing the global human appropriation of net primary production - processes, trajectories, implications: 260–269.
Kastner, T. 2007. Human appropriation of net primary production (HANPP) in the Philippines 1910-2003: A socio-ecological Analysis. Social Ecology Working Paper 92. Vienna.
Kennedy, C., Stewart, I., Facchini, A., Cersosimo, I., Mele, R., Chen, B., Uda, M., Kansal, A., Chiu, A., Kim, K., Dubeux, C,. Rovere, E. L.L., Cunha, B., Pincetl, S., Keirstead, J., Barles, S., Pusaka, S., Gunawan, J., Adegbile, M., Nazariha, M., Hoque, S., Marcotullio, P., Otharán, F. G., Genena, T., Ibrahim, N., Farooqui, R., Cervantes, G., Sahin, A. D., 2015. Energy and material flows of megacities. PNAS (112) 19, 5985-5990.
Kovanda, J. and T. Hak. 2011. Historical perspectives of material use in Czechoslovakia in 1855–2007. Ecological Indicators 11(5): 1375–1384.
Kovanda, J., Hak, T., 2007. What are the possibilities for graphical presentation of decoupling? An example of economy-wide material flow indicators in the Czech Republic. Ecological Indicators, 7: 123-132.
Krausmann, F. , Wiedenhofer, D., Lauk, C., Haas, W., Tanikawa, H., Tomer Fishman T., Miatto, A., Schandl, H., and Haberl, H. (2017). Global Socioeconomic Material Stocks Rise 23-Fold over the 20th Century and Require Half of Annual Resource Use. *Proceedings of the National Academy of Sciences* 114, no. 8 (February 21, 2017): 1880–85. https://doi.org/10.1073/pnas.1613773114.
Krausmann, F., M. Fischer-Kowalski, H. Schandl, and N. Eisenmenger. 2008. The global socio-

metabolic transition: past and present metabolic profiles and their future trajectories. Journal of Industrial Ecology 12, 637-656.

Krausmann, F., S. Gingrich, and R. Nourbakhch-Sabet. 2011. The metabolic transition in Japan: A material flow account for the period from 1878 to 2005. Journal of Industrial Ecology 15(6): 877–892.

Kuskova, P., S. Gingrich, and F. Krausmann 2008. Long term changes in social metabolism and land use in Czechoslovakia, 1830–2000: An energy transition under changing political regimes. Ecological Economics 68(1): 394–407.

La Viña, A. G., Tan, J. M., Guanzon, T. I. M., Caleda, M. J., and Ang, L., 2018. Navigating a trilemma: Energy security, equity, and sustainability in the Philippines' low-carbon transition. Energy Research & Social Science. 35, 37–47. https://doi.org/10.1016/j.erss.2017.10.039

Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013. Building Eora: A Global Multi-Region Input-Output Database At High Country And Sector Resolution. Economic Systems Research, 25, 20-49.

Lyday, T., 1994. The Mineral Industry of the Philippines. In United States Geological Survey Minerals Yearbook 1994, by United States Geological Survey. Philippines: United States Geological Survey.

Lyday, T., 2000. The Mineral Industry of the Philippines. In United States Geological Survey Minerals Yearbook 2000, by United States Geological Survey. Philippines: United States Geological Survey.

Manrique, P.L.P., J. Brun, A.C. González-Martínez, M. Walter, and J. Martínez-Alier. 2013. The Biophysical Performance of Argentina (1970–2009). Journal of Industrial Ecology 17(4): 590–604.

Martin, E., 2014. The Medium-Term Philippine Development Plan (MTPDP) and the Philippine Governance: A comparison between the Arroyo and Aquino economic governance strategies. Discussion Paper, Manila, Philippines: Philippine Institute of Developmen Studies.

Martinico-Perez, M.F., Fishman, T., Okuoka, K., Tanikawa, H., 2017. Material Flow Accounts and Driving Factors of Economic Growth in the Philippines. Journal of Industrial Ecology, Vol. 21, No. 5, p. 1226-1236. https://doi.org/10.1111/jiec.12496

Martinico-Perez M.F., Schandl, H., Fishman, T., Tanikawa, H., 2018.Socio-Economic Metabolism of an Emerging Economy: Monitoring Progress of Decoupling of Economic Growth and Environmental Pressures in the Philippines. Ecological Economics, 2018. 147, 155–166. https://doi.org/10.1016/j.ecolecon.2018.01.012

Marra Campanale, R., Femia, A., 2013. An environmentally ineffective way to increase resource productivity: Evidence from the Italian case on transferring the burden abroad. Resources 2, 608–627.

Maung, K.N., Martinico-Perez, M.F., Komatsu T., Mohammad S., Murakami S., Tanikawa, H., 2014. Comparative Studies on Driving Factors of Resource Flow in Myanmar, the Philippines and Bangladesh. Journal of Environmental Economics and Policy Studies 16, (2).

Matthews, E., C. Amann, S. Bringezu, M. Fischer-Kowalski, W. Huttler, R. Kleijn, Y. Moriguchi, C. Ottke, E. Rodenburg, D. Rogich, H. Schandl, H. Schutz, E. vander Voet, and H. Weisz. 2000. The Weight of Nations: Material Outflows from Industrial Economies. World Resource Institute.

Maung K.N., M. Martinico-Perez, T. Komatsu, S. Mohammad, S. Murakami, and H. Tanikawa 2014. Comparative Studies on Driving Factors of Resource Flow in Myanmar, the Philippines and Bangladesh. Journal of Environmental Economics and Policy Studies, Vol. 16, No. 2.

Mendoza T.C. and R. Samson. 1999. Strategies to Avoid Crop Residue Burning in the Philippine Context. Research Reports. Resource Efficient Agricultural Production (REAP).

Canada.
Mendoza T.C. and R. Samson. 2006. Relative Bioenergy Potentials of Major Agricultural Crop Residues in the Philippines. Philippine Journal of Crop Science 31(1):11-28
MMDA, 2014. Solid waste management monitoring reports of Metro Manila LGUs 2008-2013. Metro Manila Development Authority, Makati City, Philippines.
Miatto, A., Schandl, H., Fishman, T., Tanikawa, H., 2016. Global Patterns and Trends for Non-metallic Minerals used for Construction. Journal of Industrial Ecology: 1-14.
Ministry of the Environment, Government of Japan (2011). 2010 *Establishing a sound material-cycle society- Milestone toward a sound material- cycle society through changes in business and life styles.* www.env.go.jp/en/recycle/smcs/a-rep/2010gs_full.pdf
Mittermeier, R., Turner, W., Larsen, F., Brooks, T., Gascon, C., 2011. The Global Biodiversity Conservation: The Critical Role of Hotspots. In: Zachos FE, Habel JC (eds) Biodiversity hotspots: distribution and protection of conservation priority areas. Springer, Heidelberg.
Moog, F.A. 2006. Country Pasture/Forage Resource Profiles. Food and Agriculture Organization of the United Nations (FAO). http://www.fao.org/ag/agp/AGPC/doc/Counprof/PDF%20files/Philippines.pdf. Accessed on March 2014
Moog, F., 1989. Pasture Development in the Philippines. Food and Agriculture Organization. 1989. http://www.fao.org/Ag/AGP/AGPC/doc/PUBLICAT/GRASSLAN/34.pdf (Accessed on March 2016).
Moriguchi, Y., 2006. Establishing a sound material-cycle society in Asia. Paper presented at Asia 3R Conference, October 30th-November 1st, 2006, Tokyo, Japan
Moriguchi Y. and S. Hashimoto. 2016. Material Flow Analysis and Waste Management. R. Clift, A. Druckman (eds), Taking Stock of Industrial Ecology. DOI 10.1007/978-3-319-20571-7_12
Müller D.B. 2006. Stock dynamics for forecasting material flows–case study for housing in the Netherlands. Amsterdam. pp. 142–156.
National Economic Development Authority (NEDA). 2011. Philippine Development Plan (PDP) 2011 – 2016. Pasig City, Philippines.
NEDA, 2014. Philippine Development Plan 2011-2016 Midterm Update. Update Report, National Economic and Development Authority, Pasig City, Philippines: NEDA.
NEDA, 2017. AmBisyon Natin 2040. A Long Term Vision for the Philippines. http://2040.neda.gov.ph/wp-content/uploads/2016/04/A-Long-Term-Vision-for-the-Philippines.pdf (Accessed on 20 May 2017)
NSCB, 1995. Philippine Economic-Environmental and Natural Resource Accounting (PEENRA). http://www.nscb.gov.ph/peenra/Publications/asset/mineral.pdf (Accessed on January 2016).
NSCB, 1983, 1985, 1987, 1990, 1994, 1995, 1997, 2000, 2005, 2009, 2010, 2014. Philippine Statistical Yearbook.National Statistical Coordination Board. Makati City, Philippines.
NSO, 1995, 1998, 2004, 2011.Household Energy Consumption Survey (HECS). Survey Report, National Statistics Office and Department of Energy, Manila, Philippines: National Statistics Office.
NSO, 1990, 2007, 2014. Philippine Yearbook. National Statistics Office. Quezon City, Philippines.
NSWMC, 2012. National Solid Waste Management Strategy 2012-2016. National Solid Waste Management Commision. Quezon City, Philippines.
NSWMC, 2015. National Solid Waste Management Status Report (2008–2014). National Solid Waste Management Commision. Quezon City, Philippines.
OECD. 2014. Resource Productivity in the G8 and the OECD. http://www.oecd.org/environment/waste/47944428.pdf . Accessed on May 2014.

Orbeta, E.M. Indab, A.L., 1993. Estimation of Pollution Loads and Costs of Preventing Future Water Quality Deterioration in Laguna de Bay. Laguna de Bay Economic Validation Study. Technical Report No. 2.

Philippines in Figure (PIF). 2014. National Statistics Office. Quezon City, Philippines.

Philippine Statistical Yearbook. 1987-2012. National Statistical Coordination Board. Makati City, Philippines.

Philippine Mining Act (1995). Republic Act No. 7942. Congress of the Philippines, Metro Manila. http://www.mgb.gov.ph/images/stories/RA_7942.pdf , Accessed 28 May 2016

Philippine Coconut Authority. 2014. http://www.pca.da.gov.ph/magnitude.html. Accessed on April 2014.

Philippine Yearbook (PY), 1989, 1992, 1995, 1999, 2002, 2005, 2007, 2011, 2012, 2013. Philippine Yearbooks. National Statistics Office. Quezon City, Philippines.

Philippine Yearbook (PY) 2005, National Statistics Office; Quezon City, Philippines.

Philippine Yearbook (PY) 2010, National Statistics Office; Quezon City, Philippines.

Philippine Statistical Yearbook (PSY), 1983, 1985, 1987, 1990, 1994, 1997, 2000, 2009, 2014. National Statistical Coordination Board. Makati City, Philippines.

Philippine Statistical Yearbook (PSY), 2005, National Statistical Coordination Board. Makati City, Philippines.

Philippine Statistical Yearbook (PSY), 2014, National Statistical Coordination Board. Makati City, Philippines.

PSA, 2014. Compendium of Philippine Environmental Statistics 2014. Philippine Statistical Agency. Quezon City, Philippines.

PSA, 2015. Philippine Statistical Yearbook 2015. Annual Report, Manila, Philippines: Philippine Statistical Authority.

PSA, 2016. Philippine Statistical Yearbook 2016. Annual Report, Manila, Philippines: Philippine Statistical Authority.

Rapera C. L, 2005. Linking the trends in material flows with poverty in the Philippines. International Journal of Global Environmental Issues. Vol. 5. Nos. 3/ 4. Pp 181 – 193.

Retamal, M., Schandl, H., 2017. Dirty Laundry in Manila: Comparing Resource Consumption Practices for Individual and Shared Laundering: Dirty Laundry in Manila. J. of Ind. Ecol. https://doi.org/10.1111/jiec.12696

Scasny, M., J. Kovanda, and T. Hak. 2003: Material flow account, balances and derived indicators for the Czech Republic during the 1990s: results and recommendations for methodological improvements. In Ecological Economics 45, 41– 57.

Schaffartzik, A., A. Mayer, S. Gingrich, N. Eisenmenger, C. Loy, and F. Krausmann. 2014. The global metabolic transition: Regional patterns and trends of global material flows, 1950–2010. Global Environmental Change 26(0): 87–97.

Schandl et al. 2016

Schandl, H. and J. West. 2012. Material flows and material productivity in China, Australia, and Japan. Journal of Industrial Ecology 16(3): 352–364.

Schandl, H. and J. West. 2010. Resource use and resource efficiency in the Asia–Pacific region. Global Environmental Change 20(4): 636–647.

Schandl, H. and N. Schulz. 2002. Changes in the United Kingdom's natural relations in terms of society's metabolism and land-usefrom 1850 to the present day. Ecological Economics 41(2): 203–221.

Singh S., F. Kraussman, S. Gingrich, H. Haberl, K. Erb, P. Lanz, J. Martinez-Alier, and L. Temper. 2012. India's biophysical economy, 1961–2008. Sustainability in a national and global context. Ecological Economics (76) 60 – 69.

Simas, M., Pauliuk, S., Wood, R., Hertwich, E.G., Stadler, K., 2017. Correlation between production and consumption-based environmental indicators: The link to affluence and the effect on ranking environmental performance of countries. Ecological Indicators 76, 317–323. doi:https://doi.org/10.1016/j.ecolind.2017.01.026

Shi, F., T. Huang, H. Tanikawa, J. Han, S. Hashimoto, and Y. Moriguchi. 2012. Toward a Low Carbon–Dematerialization Society: Measuring the Materials Demand and CO_2 Emissions of Building and Transport Infrastructure Construction in China. Journal of Industrial Ecology 16(2):493-505

Stern, D. 2004. The Rise and Fall of the Environmental Kuznets Curve. World Development Vol. 32, No. 8 pp 1419-1439

Steinberger, J.K., Krausmann, F., Eisenmenger, N., 2010. Global patterns of materials use: a socioeconomic and geophysical analysis. Ecol. Econ. 69, 1148–1158.

Steinberger, J. K., F. Krausmann, M. Getzner, H. Schandl, and J.West. 2013. Development and dematerialization: An international study. PloS One 8(10): e70385.

Tanikawa, H., Fishman, T. Okuoka, K., and Sugimoto, K. 2015. The Weight of Society Over Time and Space A Comprehensive Account of the Construction Material Stock of Japan, 1945–2010. Journal of Industrial Ecology (19)5:778-791. DOI: 10.1111/jiec.12284

Tanikawa, H., S. Managi, and C.M. Lwin. 2014. Estimates of Lost Material Stock of Buildings and Roads Due to the Great East Japan Earthquake and Tsunami. Journal of Industrial Ecology 18(3): 421–431.

Tanikawa H. and Hashimoto, S. 2009. Urban stock over time: spatial material stock analysis using 4d-GIS, Building research & Information. Volume 37(5-6). pp. 483-502.

Tecson, G., Austria, M., Pineda, V., de Dios, L., Lapid, D., M.C., Medilo, Banzon, C., Trabajo, F.M., Mendoza, E.G., 1996. Catching Up With Asia's Tigers II. Vol. 2. 2 vols. Philippine Institute of Development Studies.

Tian, H., Whalley, J., 2010. Trade sanctions, financial transfers and BRIC participation in global climate change negotiations. Journal of Policy Modeling 32: 47-63

The Maddison-Project. 2013. http://www.ggdc.net/maddison/maddison-project/home.htm. accessed December 2015.

UN DESAPD, 2015. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/W/WP.241. United Nations Population Division Department of Economic and Social Affairs, New York (United Nations Development Programme).

UNDP and GOP., 2011. Tracking Greenhouse Gases: An Inventory Manual for Philippines. Enabling activities for the preparation of the second national communication on climate change to the UNFCCC. United Nations Development Programme (UNDP) and Government of Philippines, Manila Philippines.

UNEP, 2016.Global Material Flows and Resource Productivity: An Assessment Study of the UNEP International Resource Panel. H. Schandl, M. Fischer-Kowalski,J. West, S. Giljum, M. Dittrich, N. Eisenmenger, A. Geschke, M. Lieber, H. P. Wieland, A. Schaffartzik,F. Krausmann, S. Gierlinger, K. Hosking, M. Lenzen, H. Tanikawa, A. Miatto, and T. Fishman. Paris, United Nations Environment Programme.

UNEP, 2015.Indicators for a Resource Efficient and Green Asia and the Pacific - Measuring progress of sustainable consumption and production, green economy and resource efficiency policies in the Asia-Pacific region, Schandl, H., West, J., Baynes, T., Hosking, K., Reinhardt, W., Geschke, A., Lenzen, M. United Nations Environment Programme, Bangkok.

United Nations. 2015. 17th Session Agenda items 15 and 116. Resolution adopted by the General Assembly on 25 September 2015. A/Res/70/1 21 October 2015

UNCTAD, 2016. United Nations Conference on Trade and Development, Statistics. http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx, Accessed date: May 2016.

UNEP, 2013. Recent trends in Material Flows and Resource Productivity in Asia and the Pacific 2013. United Nations Environment Programme. Bangkok, Thailand.

UNEP, 2011a. Resource Efficiency: Economics and Outlook for Asia and the Pacific (REEO). Bangkok: Regional Office for Asia and the Pacific United Nations Environment Programme.http://www.unep.org/publications/contents/pub_details_search.asp?ID=6217.

UNEP, 2011b. Decoupling natural resource use and environmental impacts from economic growth. A report of the Working Group on Decoupling to the International Resource Panel, edited by M. Fischer-Kowalski, M. Swilling, E. U. von Weizsacker, Y. Ren, Y.Moriguchi, W. Crane, F. Krausmann, N. Eisenmenger, S. Giljum, P. Hennicke, P. Romero Lankao, and A. Siriban Manalang, S. Sewerin. Paris, France: International Resource Panel, United Nations Environment Programme).

United Nations Industrial Development Organization (UNIDO) 2009. Manila Declaration on Green Industry in Asia. https://www.unido.org/fileadmin/user_media/Services/Green_Industry/Manila_declaration.pdf. Accessed on April 2014.

United States Geological Survey (USGS). 2000-2010. The Mineral Industry of the Philippines. http://minerals.usgs.gov/minerals/pubs/country/asia.html. Accessed on November 2013.

United States Geological Survey (USGS). 2012. Minerals Yearbook: The Mineral Industry of the Philippines. http://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-rp.pdf. Accessed on January 2015.

Wang, H., S. Hashimoto, Y. Moriguchi, Q. Yue, and Z. Lu. 2012. Resource use in growing China: Past trends, influence factors and future demand. Journal of Industrial Ecology. 16(4): 481–492.

West, J., H. Schandl, F. Krausmann, J. Kovanda, T. Hak. 2014. Patterns of change in material use and material efficiency in the successor states of the former Soviet Union. Ecological Economics (105). 211-219.

West, J., and H. Schandl. 2013. Material use and material efficiency in Latin America and the Caribbean. Ecological Economics (94).19 – 27.

Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2015. The material footprint of nations. Proc. Natl. Acad. Sci. U. S. A. 112, 6271–6276.

White, T., 2000. Diet and the distribution of environmental impact. Ecol. Econ. 34 (1), 145–153.

White, T.J., 2007. Sharing resources: the global distribution of the ecological footprint. Ecol. Econ.64 (2), 402–410.

Wolman, A. 1965. The metabolism of cities. Scientific American. 213(3):179-90

World Development Indicators. 2014. http://data.worldbank.org/indicator. Accessed on 5 March 2014.

World Bank. 2016. World Development Indicators. World Bank. http://data.worldbank.org/country/philippines?view=chart, Accessed date: May 2016.

World Bank. 2017. World Development Indicators. World Bank. http://data.worldbank.org/country/philippines?view=chart, Accessed date: November 2017.

APPENDIX 1: EW-MFA INDICATORS OF THE PHILIPPINES FROM 1980 TO 2014

Unit: tonnes		1980	1981	1982	1983	1984	1985
Domestic extraction (used) (DE)		274,450,570	273,028,604	285,809,693	287,692,137	258,412,820	248,792,206
	Biomass	145,936,346	147,856,173	155,210,450	161,823,790	144,601,224	136,578,928
	Metals ores	97,508,170	94,380,377	93,309,242	87,953,871	78,586,926	83,044,815
	Nonmetallic minerals	30,183,500	30,207,630	36,245,070	36,230,614	33,477,687	27,515,398
	Fossil fuels	822,554	584,424	1,044,931	1,683,862	1,746,984	1,653,066
Direct material input (DMI)		292,536,764	289,185,002	302,348,388	304,362,953	273,617,729	263,137,395
	Biomass	147,639,636	149,556,175	157,374,837	163,915,234	146,444,656	138,650,264
	Metals ores	103,065,170	98,964,377	97,857,242	92,403,871	83,336,926	86,716,815
	Nonmetallic minerals	30,783,500	30,840,530	37,342,970	37,179,514	34,365,387	28,323,498
	Fossil fuels	11,048,458	9,823,920	9,773,339	10,864,334	9,470,760	9,446,818
Domestic material consumption (DMC)		278,452,076	274,950,627	288,108,153	289,764,705	259,617,847	248,718,244
	Biomass	141,815,442	143,946,961	151,645,566	158,450,532	141,143,930	133,024,028
	Metals ores	95,037,463	90,619,083	89,597,375	83,789,739	75,150,251	78,784,547
	Nonmetallic minerals	30,550,713	30,560,662	37,091,874	36,660,100	33,852,906	27,659,338
	Fossil fuels	11,048,458	9,823,920	9,773,339	10,864,334	9,470,760	9,250,330
Physical trade balance (PTB)		4,001,506	1,922,023	2,298,461	2,072,567	1,205,027	(73,963)
	Biomass	(4,120,904)	(3,909,212)	(3,564,884)	(3,373,258)	(3,457,293)	(3,554,899)
	Metals ores	(2,470,707)	(3,761,294)	(3,711,867)	(4,164,132)	(3,436,675)	(4,260,268)
	Nonmetallic minerals	367,213	353,032	846,804	429,486	375,219	143,940
	Fossil fuels	10,225,904	9,239,496	8,728,408	9,180,472	7,723,776	7,597,264
Domestic processed output (DPO)		96,169,060	95,494,269	100,082,779	100,313,533	90,357,029	89,662,193
	Air	81,529,674	80,609,387	84,828,639	84,832,717	74,742,454	74,046,310
	Land	5,189,968	5,334,357	5,482,500	5,634,327	5,789,701	5,948,440
	Water	2,063,877	2,121,296	2,180,207	2,240,584	2,302,371	2,365,496
	Dissipative Flow	7,385,540	7,429,229	7,591,432	7,605,906	7,522,503	7,301,947
Balancing	Air and water Input	111,256,876	109,638,997	113,936,756	115,248,050	103,875,622	94,576,456
	Water and air Output	120,117,608	120,758,078	124,518,858	126,257,704	119,200,695	115,881,563
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS							
	Input side	403,793,640	398,824,000	416,285,145	419,611,003	377,493,351	357,713,851
	Output side	403,793,640	398,824,000	416,285,145	419,611,003	377,493,351	357,713,851

APPENDIX A

Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes	1986	1987	1988	1989	1990
Domestic extraction (used) (DE)	251,393,189	245,597,158	253,860,200	258,180,118	240,788,178
Biomass	135,731,060	131,534,238	138,561,808	146,462,560	135,054,163
Metals ores	82,402,622	78,673,480	77,328,905	71,419,084	64,244,408
Nonmetallic minerals	31,680,279	33,942,014	36,336,446	38,697,363	40,006,865
Fossil fuels	1,579,228	1,447,426	1,633,042	1,601,112	1,482,742
Direct material input (DMI)	266,857,311	264,396,335	275,187,626	281,002,561	267,605,446
Biomass	137,596,682	133,459,460	141,309,288	150,126,106	140,098,952
Metals ores	86,733,622	84,143,480	82,380,905	76,899,084	69,888,408
Nonmetallic minerals	32,923,779	35,334,914	37,863,646	40,088,063	42,507,378
Fossil fuels	9,603,228	11,458,481	13,633,788	13,889,309	15,110,708
Domestic material consumption (DMC)	251,766,208	248,647,502	258,582,934	268,014,733	253,114,262
Biomass	131,459,691	127,892,172	136,105,820	145,017,517	134,228,577
Metals ores	78,936,367	75,295,281	72,534,706	70,737,884	63,376,757
Nonmetallic minerals	32,084,325	34,444,926	36,973,657	38,848,649	41,179,134
Fossil fuels	9,285,824	11,015,124	12,968,751	13,410,684	14,329,795
Physical trade balance (PTB)	373,019	3,050,344	4,722,733	9,834,615	12,326,084
Biomass	(4,271,369)	(3,642,066)	(2,455,988)	(1,445,043)	(825,587)
Metals ores	(3,466,255)	(3,378,199)	(4,794,199)	(681,200)	(867,650)
Nonmetallic minerals	404,047	502,912	637,212	151,286	1,172,269
Fossil fuels	7,706,596	9,567,698	11,335,709	11,809,572	12,847,053
Domestic processed output (DPO)	92,169,236	100,771,517	107,202,013	115,088,014	119,915,806
Air	76,291,180	84,888,433	90,948,685	98,518,108	102,553,800
Land	6,110,529	6,275,751	6,443,461	6,612,833	6,783,234
Water	2,429,954	2,495,657	2,562,350	2,629,703	2,697,466
Dissipative Flow	7,337,573	7,111,676	7,247,518	7,327,370	7,881,307
Balancing					
Air and water Input	99,256,001	107,826,261	113,580,116	123,335,686	128,296,150
Water and air Output	118,013,169	120,817,314	125,703,582	131,449,165	131,699,674
Net additions to stock (NAS)	140,839,804	134,884,932	139,257,455	144,813,240	129,794,932
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
Input side	366,113,312	372,222,596	388,767,742	404,338,247	395,901,596
Output side	366,113,312	372,222,596	388,767,742	404,338,247	395,901,596

APPENDIX A

Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes	1991	1992	1993	1994	1995
Domestic extraction (used) (DE)	239,632,457	240,590,894	242,881,232	258,774,869	255,292,112
Biomass	140,417,726	138,935,790	145,360,825	151,803,264	141,154,334
Metals ores	57,438,735	51,816,493	53,250,273	48,739,498	46,614,148
Nonmetallic minerals	40,320,320	47,731,447	42,235,486	56,658,449	66,123,085
Fossil fuels	1,455,676	2,107,164	2,034,648	1,573,658	1,400,544
Direct material input (DMI)	264,563,206	268,927,705	272,181,393	289,823,956	293,005,170
Biomass	144,018,518	143,298,653	150,643,248	157,096,573	147,867,743
Metals ores	63,084,735	58,086,493	59,799,273	55,529,368	55,287,531
Nonmetallic minerals	41,870,520	50,029,447	43,808,086	58,269,848	68,368,985
Fossil fuels	15,589,433	17,513,112	17,930,786	18,928,168	21,480,911
Domestic material consumption (DMC)	249,869,732	255,340,073	257,851,424	274,763,173	277,148,207
Biomass	138,427,885	137,931,854	144,665,889	151,311,185	141,413,896
Metals ores	56,496,825	52,228,432	53,802,489	48,806,664	48,866,284
Nonmetallic minerals	40,237,265	48,422,398	42,137,448	56,382,192	66,248,641
Fossil fuels	14,707,756	16,757,389	17,245,597	18,263,131	20,619,386
Physical trade balance (PTB)	10,237,274	14,749,179	14,970,192	15,988,304	21,856,096
Biomass	(1,989,840)	(1,003,936)	(694,936)	(492,078)	259,562
Metals ores	(941,910)	411,940	552,216	67,167	2,252,136
Nonmetallic minerals	(83,055)	690,950	(98,037)	(276,257)	125,556
Fossil fuels	13,252,080	14,650,225	15,210,949	16,689,473	19,218,842
Domestic processed output (DPO)	120,429,588	126,737,580	112,656,443	126,345,047	121,395,115
Air	103,141,140	108,930,295	94,359,611	107,725,818	101,832,395
Land	6,954,338	7,126,140	7,298,717	7,472,295	7,647,011
Water	2,765,509	2,833,828	2,902,457	2,971,483	3,040,961
Dissipative Flow	7,568,601	7,847,318	8,095,658	8,175,452	8,874,748
Balancing					
Air and water Input	126,909,029	134,051,736	118,988,554	131,024,415	127,553,350
Water and air Output	132,792,107	135,498,173	134,111,612	138,936,154	140,961,586
Net additions to stock (NAS)	123,557,065	127,156,055	130,071,922	140,506,386	142,344,857
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
Input side	391,472,235	402,979,441	391,169,947	420,848,371	420,558,520
Output side	391,472,235	402,979,441	391,169,947	420,848,371	420,558,520

APPENDIX A
Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes	1996	1997	1998	1999	2000
Domestic extraction (used) (DE)	282,486,697	289,561,023	279,279,209	278,220,388	285,598,841
Biomass	156,102,621	156,984,074	139,377,223	160,145,067	159,213,530
Metals ores	40,825,787	38,956,323	39,493,825	35,068,133	38,525,813
Nonmetallic minerals	84,050,226	92,496,509	99,204,035	81,748,600	86,440,338
Fossil fuels	1,508,063	1,124,117	1,204,126	1,258,588	1,419,160
Direct material input (DMI)	325,273,557	332,663,154	321,824,826	320,225,611	331,417,800
Biomass	165,394,277	165,881,485	149,909,833	168,917,086	168,861,090
Metals ores	49,591,555	46,549,611	46,382,390	42,203,147	45,588,310
Nonmetallic minerals	86,478,326	94,629,609	100,501,235	83,990,800	89,827,338
Fossil fuels	23,809,399	25,602,449	25,031,368	25,114,578	27,141,063
Domestic material consumption (DMC)	309,837,124	316,449,666	306,342,327	305,307,713	313,353,991
Biomass	159,593,148	159,650,739	143,773,502	164,515,788	163,113,794
Metals ores	43,325,892	40,091,680	39,764,664	34,800,947	37,832,690
Nonmetallic minerals	84,479,063	92,404,642	98,422,715	81,964,642	87,463,080
Fossil fuels	22,439,021	24,302,606	24,381,447	24,026,337	24,944,428
Physical trade balance (PTB)	27,350,427	26,888,643	27,063,118	27,087,325	27,755,150
Biomass	3,490,527	2,666,664	4,396,278	4,370,721	3,900,263
Metals ores	2,500,105	1,135,357	270,839	(267,186)	(693,122)
Nonmetallic minerals	428,837	(91,867)	(781,319)	216,042	1,022,742
Fossil fuels	20,930,958	23,178,488	23,177,321	22,767,748	23,525,267
Domestic processed output (DPO)	129,140,394	143,263,029	152,678,294	146,697,560	156,061,005
Air	106,753,665	120,616,657	130,120,275	123,348,951	132,383,001
Land	9,126,125	9,331,193	9,537,333	9,745,437	9,955,845
Water	3,110,705	3,180,604	3,250,868	3,321,802	3,393,521
Dissipative Flow	10,149,899	10,134,576	9,769,817	10,281,369	10,328,639
Balancing					
Air and water Input	131,237,189	143,881,346	149,824,563	139,859,017	139,499,358
Water and air Output	150,016,186	156,872,647	156,983,848	160,143,149	161,875,514
Net additions to stock (NAS)	161,917,733	160,195,337	146,504,749	138,326,021	134,916,831
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
Input side	456,510,746	476,544,500	471,649,389	460,084,628	470,917,158
Output side	456,510,746	476,544,500	471,649,389	460,084,628	470,917,158

APPENDIX A

Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes	2001	2002	2003	2004	2005
Domestic extraction (used) (DE)	294,247,377	306,969,067	311,862,586	328,822,109	329,893,835
Biomass	162,662,828	170,512,641	178,572,813	187,586,628	185,667,888
Metals ores	34,713,451	35,009,667	36,919,432	33,928,656	35,913,853
Nonmetallic minerals	95,466,268	98,234,479	92,205,994	102,598,588	102,825,899
Fossil fuels	1,404,830	3,212,280	4,164,347	4,708,237	5,486,194
Direct material input (DMI)	338,220,787	353,082,360	354,263,194	369,426,914	372,493,646
Biomass	172,489,004	181,499,342	187,957,717	196,135,041	196,219,312
Metals ores	41,831,914	43,040,345	44,485,068	40,370,019	42,967,504
Nonmetallic minerals	98,729,385	99,475,215	94,191,443	104,606,752	104,956,779
Fossil fuels	25,170,485	29,067,458	27,628,966	28,315,103	28,350,051
Domestic material consumption (DMC)	322,174,240	336,512,090	336,026,238	351,889,520	348,961,286
Biomass	166,353,533	175,612,072	181,933,761	190,296,139	188,655,861
Metals ores	35,364,914	36,496,345	37,216,068	32,081,571	32,639,708
Nonmetallic minerals	96,504,542	97,340,215	91,605,443	102,612,428	101,591,939
Fossil fuels	23,951,252	27,063,458	25,270,966	26,899,381	26,073,778
Physical trade balance (PTB)	27,926,864	29,543,023	24,163,652	23,067,411	19,067,451
Biomass	3,690,705	5,099,430	3,360,948	2,709,511	2,987,972
Metals ores	651,464	1,486,678	296,636	(1,847,085)	(3,274,145)
Nonmetallic minerals	1,038,274	(894,264)	(600,551)	13,841	(1,233,960)
Fossil fuels	22,546,421	23,851,178	21,106,619	22,191,145	20,587,584
Domestic processed output (DPO)	154,966,285	162,743,932	166,263,309	172,008,388	168,505,978
Air	131,058,346	138,387,026	138,692,297	145,422,867	141,100,562
Land	10,169,480	10,385,357	12,864,916	11,514,577	12,674,740
Water	3,466,340	3,539,923	3,612,963	3,683,701	3,750,983
Dissipative Flow	10,272,119	10,431,627	11,093,133	11,387,242	10,979,693
Balancing					
Air and water Input	137,630,270	147,717,634	147,937,587	154,846,249	147,366,159
Water and air Output	163,360,299	170,542,790	173,692,414	178,278,351	176,846,787
Net additions to stock (NAS)	141,477,926	150,943,002	144,008,102	156,449,030	150,974,680
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
Input side	475,851,057	500,799,994	502,200,781	524,273,163	519,859,805
Output side	475,851,057	500,799,994	502,200,781	524,273,163	519,859,805

APPENDIX A

Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes	2006	2007	2008	2009	2010
Domestic extraction (used) (DE)	345,573,585	371,063,131	393,266,393	408,606,772	418,297,068
Biomass	193,561,755	196,740,809	210,308,254	204,672,834	194,144,085
Metals ores	38,098,628	45,512,997	40,697,734	51,619,178	61,973,340
Nonmetallic minerals	108,926,565	122,131,502	133,834,407	142,645,900	150,537,235
Fossil fuels	4,986,636	6,677,822	8,425,999	9,668,860	11,642,407
Direct material input (DMI)	388,883,023	413,358,487	437,165,279	448,078,291	465,793,515
Biomass	204,828,089	207,058,415	221,282,568	216,576,971	205,762,842
Metals ores	44,988,356	51,703,108	46,407,454	55,712,026	68,379,924
Nonmetallic minerals	110,610,748	123,825,166	135,952,496	144,380,628	152,504,840
Fossil fuels	28,455,830	30,771,797	33,522,760	31,408,667	39,145,909
Domestic material consumption (DMC)	357,826,877	375,264,057	400,435,218	413,657,464	419,484,000
Biomass	196,731,762	198,103,241	210,800,215	208,535,394	195,168,713
Metals ores	29,015,509	31,973,184	30,047,790	38,571,285	45,855,384
Nonmetallic minerals	106,560,725	118,621,129	130,499,090	140,079,284	146,571,422
Fossil fuels	25,518,881	26,566,502	29,088,123	26,471,501	31,888,481
Physical trade balance (PTB)	12,253,291	4,200,926	7,168,825	5,050,692	1,186,932
Biomass	3,170,007	1,362,432	491,961	3,862,560	1,024,628
Metals ores	(9,083,119)	(13,539,813)	(10,649,944)	(13,047,893)	(16,117,956)
Nonmetallic minerals	(2,365,841)	(3,510,373)	(3,335,317)	(2,566,615)	(3,965,813)
Fossil fuels	20,532,245	19,888,680	20,662,125	16,802,641	20,246,073
Domestic processed output (DPO)	179,216,669	177,917,091	188,079,514	194,049,100	201,316,391
Air	141,424,470	149,293,688	159,432,462	164,192,698	171,800,481
Land	22,976,045	13,575,908	13,698,569	14,833,514	14,460,518
Water	3,814,189	3,873,959	3,931,943	3,990,500	4,051,332
Dissipative Flow	11,001,965	11,173,537	11,016,540	11,032,388	11,004,059
Balancing					
Air and water Input	148,843,608	154,336,356	157,580,367	163,950,148	163,398,928
Water and air Output	180,224,299	184,102,079	189,474,821	190,346,577	189,135,865
Net additions to stock (NAS)	147,229,517	167,581,244	180,461,250	193,211,935	192,430,673
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
Input side	537,726,632	567,694,843	594,745,646	612,028,440	629,192,443
Output side	537,726,632	567,694,843	594,745,646	612,028,440	629,192,443

APPENDIX A

Material Flow Indicators of the Philippines from 1980 to 2014

Unit: tonnes		**2011**	**2012**	**2013**	**2014**
Domestic extraction (used) (DE)		474,256,608	491,149,481	566,305,388	598,258,705
	Biomass	215,508,860	215,471,499	211,416,547	214,420,263
	Metals ores	63,291,610	55,799,544	63,955,154	73,278,873
	Nonmetallic minerals	182,018,567	206,354,845	276,347,725	294,363,717
	Fossil fuels	13,437,572	13,523,593	14,585,962	16,195,853
Direct material input (DMI)		520,472,483	542,400,892	619,566,579	660,503,518
	Biomass	226,349,898	225,976,406	220,922,790	228,026,019
	Metals ores	70,272,032	66,937,362	75,831,345	86,531,435
	Nonmetallic minerals	183,669,832	207,752,623	277,678,412	296,444,643
	Fossil fuels	40,180,722	41,734,501	45,134,032	49,501,421
Domestic material consumption (DMC)		461,088,093	487,128,605	545,992,075	577,300,312
	Biomass	211,518,737	212,319,581	204,072,424	209,967,133
	Metals ores	38,137,460	37,655,061	36,174,432	41,722,641
	Nonmetallic minerals	176,632,761	201,043,979	267,903,049	285,537,750
	Fossil fuels	34,799,136	36,109,984	37,842,169	40,072,788
Physical trade balance (PTB)		(13,168,515)	(4,020,876)	(20,313,313)	(20,958,394)
	Biomass	(3,990,123)	(3,151,918)	(7,344,122)	(4,453,130)
	Metals ores	(25,154,150)	(18,144,482)	(27,780,722)	(31,556,232)
	Nonmetallic minerals	(5,385,805)	(5,310,866)	(8,444,676)	(8,825,966)
	Fossil fuels	21,361,564	22,586,391	23,256,207	23,876,935
Domestic processed output (DPO)		208,545,372	220,038,084	246,557,835	262,562,614
	Air	175,277,174	191,130,155	216,232,571	231,235,572
	Land	18,315,528	14,441,561	16,272,552	15,673,359
	Water	4,115,009	4,181,026	4,248,710	4,316,945
	Dissipative Flow	10,837,661	10,285,342	9,804,001	11,336,738
Balancing	Air and water Input	159,056,485	170,139,422	177,859,562	189,076,674
	Water and air Output	188,781,955	191,652,453	194,299,430	199,526,089
Net additions to stock (NAS)		222,817,252	245,577,490	282,994,372	304,288,283
National Material Balance Equation: DE + Imports + Input Balancing Items = Exports + DPO + Output Balancing Items + NAS					
	Input side	679,528,968	712,540,314	797,426,141	849,580,192
	Output side	679,528,968	712,540,314	797,426,141	849,580,192

APPENDIX 2: DOMESTIC EXTRACTION PER PROVINCE IN THE PHILIPPINES, 2013

Region		Province	Biomass	Fossil Fuels	Non-metallics	Metallics	Domestic Extraction
CAR (Cordillera Admin Region)	1	Abra	0.63	-	0.15	-	0.78
	2	Apayao	0.45	-	-	-	0.45
	3	Benguet	0.53	-	4.04	7.48	12.05
	4	Ifugao	0.62	-	-	-	0.62
	5	Kalinga	0.77	-	-	-	0.77
	6	Mountain Province	0.23	-	-	-	0.23
Region I (Ilocos Region) Except Baguio City	7	Ilocos N	1.77	-	3.95	-	5.71
	8	Ilocos S	1.52	-	3.48	-	5.00
	9	La Union	1.14	-	7.32	-	8.47
	10	Pangasinan	6.25	-	37.56	-	43.81
Region II (Cagayan Valley)	11	Batanes	0.05	-	-	-	0.05
	12	Cagayan	4.73	-	6.34	0.72	11.79
	13	Isabela	8.50	-	4.34	-	12.84
	14	Nueva Vizcaya	1.24	-	4.38	-	5.61
	15	Quirino	0.99	-	2.31	-	3.30
Region III (Central Luzon) except Angeles City and Olongapo City	16	Aurora	0.73	-	-	-	0.73
	17	Bataan	0.80	-	2.10	0.07	2.96
	18	Bulacan	2.10	-	15.58	-	17.69
	19	Nueva Ecija	5.78	-	2.37	-	8.15
	20	Pampanga	2.59	-	4.27	-	6.86
	21	Tarlac	4.28	-	2.04	-	6.32
	22	Zambales	0.87	-	0.69	4.65	6.21
Region IV-A (Calabarzon) Except Lucena City	23	Batangas	4.83	-	7.00	-	11.82
	24	Cavite	1.90	-	2.23	-	4.14
	25	Laguna	1.58	-	8.08	-	9.66
	26	Quezon	3.33	-	8.17	-	11.49
	27	Rizal	1.63	-	31.69	-	33.31
Region IV-B (MIMAROPA) Except Puerto Princesa City	28	Marinduque	0.29	-	-	-	0.29
	29	Mindoro Occ	1.30	-	0.40	-	1.70
	30	Mindoro Or	1.95	-	-	-	1.95
	31	Palawan	2.57	3.03	1.62	7.14	14.36
	32	Romblon	0.87	-	-	-	0.87
Region V (Bicol Region)	33	Albay	1.68	0.05	-	2.98	4.70
	34	Camarines N	1.23	-	4.63	-	5.86
	35	Camarines S	3.61	-	2.18	-	5.79
	36	Catanduanes	0.60	-	0.09	-	0.68

Region	Province		Biomass	Fossil Fuels	Non-metallics	Metallics	Domestic Extraction
	38	Sorsogon	1.34	-	0.06	-	1.40
Region VI (Western Visayas) except Ilo ilo City	39	Aklan	0.81	-	3.62	-	4.43
	40	Antique	1.33	10.18	0.25	-	11.76
	41	Capiz	2.42	-	0.36	-	2.78
	42	Guimaras	0.60	-	0.15	-	0.74
	43	Iloilo	5.58	-	1.58	-	7.16
Region VII (Central Visayas) except Cebu City	44	Bohol	3.14	-	7.45	-	10.59
	45	Cebu	2.03	0.17	22.71	11.06	35.97
	46	Siquijor	1.72	-	0.08	-	1.80
NIR (Except Bacolod City) Negros Island Region	47	Negros Or	5.29	-	4.19	-	9.47
	48	Negros Occ	24.20	0.01	3.43	-	27.65
Region VIII (Eastern Visayas) except Tacloban City	49	Biliran	0.55	-	-	-	0.55
	50	E Samar	0.73	-	0.27	-	1.01
	51	Leyte	3.20	-	2.50	-	5.70
	52	N Samar	1.55	-	0.24	-	1.78
	53	S Leyte	1.10	-	-	-	1.10
Samar (	54	W Leyte	0.65	-	-	-	0.65
Region IX (Zamboanga Peninsula) except Isabela and ZamCity	55	Zamboanga dN	2.29	-	2.70	15.53	20.52
	56	Zamboanga dS	3.00	0.32	2.62	-	5.94
	57	Zamboanga Sibugay	1.66	-	-	-	1.66
Region X (Northern Mindanao) except Iligan City and CDO	58	Bukidnon	13.09	-	2.28	-	15.37
	59	Camiguin	0.43	-	1.62	-	2.05
	60	Lanao dN	3.26	-	5.04	-	8.30
	61	Misamis Occ	1.61	-	2.95	-	4.57
	62	Misamis Or	2.52	-	4.71	-	7.23
Region XI (Davao Region) except Davao City and Davao Occ	63	Davao dN	3.95	-	2.94	-	6.89
	64	Davao dS	4.46	-	2.16	-	6.63
	65	Davao Oriental	1.96	-	2.12	-	4.08
	66	Compostela Valley	2.78	-	-	0.68	3.46
Region XII SOCCKSARGEN) except GenSan, Davao City & Cotabato city	67	N Cotabato	5.51	-	-	-	5.51
	68	Sarangani	2.14	-	0.79	-	2.93
	69	S Cotabato	5.06	-	0.85	-	5.91
	70	Sultan Kudarat	2.87	-	0.70	-	3.56
Region XIII	71	Agusan dN	1.35	-	4.27	-	5.62

Region	Province		Biomass	Fossil Fuels	Non-metallics	Metallics	Domestic Extraction
(CARAGA) except Butuan City	72	Agusan dS	2.63	-	2.62	1.52	6.77
	73	Dinagat Islands	0.18	-	-	0.73	0.91
	74	Surigao dN	0.87	-	5.11	11.46	17.43
	75	Surigao dS	1.58	0.01	2.41	10.56	14.55
ARMM Except Isabela City	76	Basilan	0.79	-	-	-	0.79
	77	Lanao dS	2.18	-	-	-	2.18
	78	Maguindanao	3.66	-	-	-	3.66
	79	Sulu	1.42	-	-	-	1.42
	80	Tawi-tawi	1.15	-	-	-	1.15

APPENDIX 3: ESTIMATION FACTORS

1. Ratio of gross ore and metal content.

Gross ore/metal content	1988	1994
Gold	892,651 (0.0001%)	430,491 (0.00023%)
Copper	238 (16%)	233 (26%)
Chromite	6.6 (15%)	3.8 (26%)
Nickel	41.7 (2.4%)	41.7 (2.4%)
Manganese	1.9 (52%)	1.9 (52%)

Source: Environment and Natural Resource Accounts: Philippine Mineral Resources. 1995. Accessed from http://www.nscb.gov.ph/peenra/Publications/asset/mineral.pdf

2. Consumption of Fuel wood

2.1 Number of Household Energy Consumption Survey

	1989	1995	2004	2011
Total No of HH	10,534	12,644	16,640	20,969
Fuel wood, %HH	67.10	63.50	55.30	54.20
Charcoal, %HH	32.10	38.50	34.20	36.40
Biomass, %HH	46.40	29.20	18.90	22.30

Source: National Statistics Office Philippines

2.2 Biomass based energy consumption per head

Energy Sources	Tonnes/yr
Fuelwood	0.309
Charcoal	0.029
Biomass	0.0053

Source: DOE 1996, as mentioned in Rose et al, (2009) Criteria and Indicator for Sustainable Woodfuels: Case Studies from Brazil, Guyana, Nepal, Philippines and Tanzania) Published by FAO

3. Grazed Biomass

Demand Side Approach: feed balance to identify demand for grazed biomass

Roughage requirement	Tonnes/head/y
Rice Straw	0.889
Corn Stover & Cobs	0.448
Beans and Peas Hay	0.005
Camote Vine	0.032
Cassava Leaves	0.012
Peanut hay	0.006
Sugar cane tops	0.136
Ramie Leaves	0.001
Coconut	0.333
Rubber	0.038
Grassland	1.800

Source: F.A. Moog. Pasture Development in the Philippines. Accessed at http://www.fao.org/ag/agp/agpc/doc/publicat/GRASSLAN/34.pdf

4. Crops Residues

Step 1: Identification of crops that provide residues for further socio-economic use

Step 2: Estimation of available crop residues via harvest factors

Available crop residues [t(as is weight)] = primary crop harvest [t(as is weight)] * harvest factor

Step 3: Estimation of fraction of used residues

Used crop residues [t (as is weight] = available crop residues [t (as is weight)] * recovery rate

Crops Residues	Harvest Factor	Recovery Rate
Rice Hull	0.2	0.91 x 0.9
Corn Cobs	0.227	0.8
Coconut (with husk)	1.2 x 0.3	0.6
Sugar cane Baggase	0.28	from gross cane milled
Palay (Grain to Rice Straw Ratio)	1.5	0.7
Maize (grain to straw)	2	0.39
Sugarcane tops & trash	0.65	

APPENDIX 4: CROSS CUTTING LAWS AND POLICIES

Cross cutting laws and policies on resource and environmental management, sustainable development, green growth and energy efficiency in the Philippines

Government Policy	Main Thrust
Republic Act (RA) No. 7586 National Integrated Protected Areas System Act	Provides for establishment and management of protected areas in the country (e.g. forest areas, marine and aquatic resources)
Republic Act (RA) No. 8435 Agriculture and Fisheries Modernization Act (AFMA)	Primary policy in the development of the agriculture and fisheries sector; Seven core principles: a) poverty alleviation and social equity; b) food security; c) rational use of resources; d) global competitiveness; e) sustainable development; f) people empowerment; g) protection from unfair competition
Strategic Agricultural and Fisheries Development Zones (SAFDZ) under AFMA	Creation of a system of zone-based management on based on the principle of using efficiency in assigning agricultural areas for food production, security and environmental protection
Republic Act (RA) 8550 The Philippine Fisheries Code	• National policy on sustainable use of fishery resources; • Establishment of fish refuge and marine sanctuaries; • Cultivation and conversion of mangroves; Prohibitions and penalties to the collection, possession, selling and export of all types of corals, white sand, silica, pebbles and other materials that make up the marine habitat • Establishment of Fisheries and Aquatic Resources Management Councils (FARMCs)
Clean Air Act of 1999	An Act providing for a comprehensive air pollution control policy and a national program to prevent, manage, control, and reverse air pollution through both regulatory and market- based instruments.
Ecological Solid Waste Management Act	An Act setting up a national program for managing the transfer, transport, processing, and disposal of solid waste. It calls for a phasing out of open dumpsites and converting them into sanitary landfills.
Republic Act (RA) No. 9275 The Philippine Clean Water Act	Main policy in providing comprehensive water quality management; protection of fresh, brackish and marine waters from land-based sources of pollution

Government Policy	Main Thrust
Executive Order No. 318	Adoption of Sustainable Forest Management (SFM) as the official policy framework for all plans and programs in the sector
Biofuels Act	An Act establishing the framework for the promotion of the use of biofuels in road transport (biodiesel and gasoline blended with bioethanol).
Renewable Energy Act	An Act establishing the framework for the accelerated development of renewable energy resources.
Republic Act (RA) No. 9729 Climate Change Act	• Mainstreaming of climate change into government formulation of programs and projects, plans and strategies, and policies • Creation of the Climate Change Commission • Establishment of Framework Strategy and Program on climate change
Executive Order No. 23 Executive Order No. 26	Moratorium on the cutting and harvesting of timber in natural forest and creation of the Anti-Illegal Logging Task Force Establishment of the National Greening Program (NGP), a convergence initiative to harmonize all greening efforts/initiatives of the government
Philippine Energy Plan 2012-2030	Targets for Low Carbon Scenario in 2030 1. Triple renewable energy capacity by 2030 2. 90% household electrification by 2017 and 100% *sitio (*smallest unit of communities*)* energization by 2015 3. 30% of all public utility vehicles will run on alternative fuels (CNG for buses; Auto LPG for taxis) 4. Implement higher biofuels blend (20%) 5. 10% energy savings on the total energy demand
Energy Efficiency and Conservation Roadmap 2014–2030 >Short Term:2017-2019 >Medium Term: 2020-2022 >Long Term: 2023-2040 The Department of Energy is promoting partnership with	*Programs:* The energy efficiency program is focused on major energy intensive sectors namely; industrial, residential, and commercial as well as big oil consuming sectors such as power, industry and transport. General Programs: Information campaigns on energy conservation awareness **Industries:** Companies with >1M FOEL/y are required to submit energy consumption reports, >2M FOEL/y must submit annual energy conservation programs and energy efficiency targets. Awards are given to those who have undertaken and

Government Policy	Main Thrust
private sectors for development and implementation of energy efficient technologies.	implemented energy efficiency and conservation programs. **Residential:** Energy labeling and efficiency standards: air-conditioners, refrigerators, freezers, lamp ballasts. **Transport:** Use of compressed natural gas for as alternative fuel to diesel
Executive Order No. 5, s. 2016: AmBisyon Natin 2040 (The Philippines by 2040)	Guide for development planning. The country is a prosperous middle class society where no one is poor. People live long and healthy lives and are smart and innovative. The Philippines is a high-trust society where families thrive in vibrant, culturally diverse, and resilient communities
The Philippine Development Plan 2017-2022	Provides the policy priorities and targets of the country from 2017 to 2022, based on the long-term vision of Philippine 2040. The PDP targets and policy priorities to lay down the foundations for sustainable development.

APPENDIX 5: PEER REVIEWED PUBLICATIONS

1. **Material Flow Accounts and Driving Factors of Economic Growth in the Philippines**
Marianne Faith G. Martinico-Perez, Tomer Fishman, Keijiro Okuoka and Hiroki Tanikawa
Journal of Industrial Ecology, 2017. Vol. 21, No. 5, p. 1226-1236.
https://doi.org/10.1111/jiec.12496

2. **Socio-Economic Metabolism of an Emerging Economy: Monitoring Progress of Decoupling of Economic Growth and Environmental Pressures in the Philippines**
Marianne Faith G. Martinico-Perez, Heinz Schandl, Tomer Fishman, Hiroki Tanikawa
Ecological Economics, 2018. 147, 155–166.
https://doi.org/10.1016/j.ecolecon.2018.01.012

3. **Sustainability Indicators from Resource Flow Trends in the Philippines**
Resource Conservation and Recycling (in print)
Marianne Faith G. Martinico-Perez, Heinz Schandl, Hiroki Tanikawa