# Socio-economic Metabolism of Canada: A case study of Biomass and Energy flows from 1990-2011

by

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AUTHORS DECLARATION

I hereby declare I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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# Abstract

Canada is ranked eighth, both as one of world's leading producer of food as well as consumer of world's total primary energy supply. Furthermore, Canada is one of the largest biomass and energy exporter, playing an important role towards world's resource consumption. To understand Canada's part in sustainable biomass production and energy security, it is important to analyze production, consumption and trade flows related to biomass and energy.

Using the MEFA indicators, this study attempts to operationalize biomass and energy metabolism of Canada. The data reflecting biomass incorporates the food, feed, forestry and other uses such as tobacco, and the data for energy contains food & feed, renewable and non-renewable energy sources. The research answers the following three questions: i) how has the metabolic profile of Canada changed over time, ii) How does Canada compare to other nations such as US in terms of biomass and energy use? iii) Where are potentials for a sustainability transition in biomass and energy sector?

Results indicate that Canada is self-dependent on biomass and energy consumption except for few food crops. Canada exports 30% of the biomass domestically produced and imports only 10% of the total biomass consumed locally. 54% of the technical energy domestically extracted is used for exports whereas 29% of the locally consumed technical energy comes from imports. This study further relates food & feed towards Canada's total energy metabolism. The thesis also adds to the growing research of social metabolism and provides data points of Canada for global MEFA database. The study also encourages the discussion on food and energy security by providing key insights for the policy makers.



Keywords: Canada, Biomass, Energy, MEFA, Social Metabolism, Food Security, Energy Security, Sustainability Transition

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# Chapter 1 Introduction

## 1.1 Background

Human development throughout history has been driven by extraction and consumption of natural resources. In other words the economic process is heavily relied on continuous inputs from the natural environment (Behrens et al., 2007). Therefore, to fuel the human progress over the last centuries, the throughput of material and energy has increased many-fold. The increased use of natural resources has brought social and environmental challenges (UNEP, 2016). The high throughput of material is not only because of the exponential increase in the human population but also as a result of desired economic growth and industrialization of economies (Krausmann et al., 2016). During the last century, the human population has grown by four times whereas GDP grew by twenty times (Maddison, 2001). Additionally, the global material use amplified by a factor of 19 and energy use by a factor of 14 (Krausmann et al., 2016). In 2009 730 EJ of energy and 64 Gt of material were extracted by mankind to fulfill its requirement (Krausmann et al., 2016). As developing economies such as the Asia Pacific region are moving from biomass based agrarian economies to mineral based industrial economies, demand for raw materials has increased by 4-fold in past three decades (Schandl & West, 2010). The growing material need has put a further stress on biosphere and geosphere resulting in a rapid exhaustion of resources (Singh et al., 2012).

The extensive resource extraction and waste from the output of these materials have passed the planetary boundaries to provide these resources (Giljum et al., 2014). This is true for both renewable, where they are being extracted faster than biosphere can regenerate and for non-renewable resources whose extraction creates environmental burden, industrial waste and pollution (Giljum et al., 2014).

Strategies have been defined to overcome the environment, ecological and social implication of increasing resource extraction in terms of resource efficiency, decoupling of material from economic growth and sustainable use of resources (UNEP, 2011) with less or no effect to the resource extraction and consumption (Schaffartzik et al.,2014). The depletion of biodiversity (MEA, 2005) and greenhouse gas emissions (IPCC, 2007), are growing at a fast pace. With current rate of material usage in the industrial world and increasing requirement from the agrarian economies plus the expected increase in the global population, the global resource use is expected to grow three folds (Rockström et al., 2009) which will outgrow the Earth's capacity to generate materials. It is therefore imperative that the material growth needs operate within what nature can deliver and for mankind to use it in a sustainable manner (Krausmann et al., 2016).

To achieve this, it is important to understand the global and national patterns of material extraction, consumption and trade to discover opportunities of a sustainability transition (Schaffartzik et al., 2016) as these are the factors of growing socio-economic metabolism, which in turn is endangering our sustainable future (Krausmann et al., 2016).

## 1.2 Material and Energy Flow Analysis (MEFA)

MEFA is an accounting method to quantify throughput of material and energy through an economic system, from extraction, production and waste disposal. MEFA also considers resource exchange from other socio-economic systems through trade. To analyze resource consumption, Economy Wide Material & Energy Flow Analysis (EW-MEFA) is the most consistent and customary methodology used in the international arena (Giljum et al., 2014). MEFA enables researchers and analysts to record flows of material and energy between nature and society (domestic extraction) and flows which occur between two or more economic boundaries (imports and exports) (Fischer-Kowalski & Weisz, 1999). Since MEFA accounts for biophysical quantities of material, it also takes into consideration materials with negligible monetary value that cannot be separated from economic activities (crops residues, bark from wood) (Krausmann et al., 2004).

MEFA incorporates two categories, i) Material Flow Analysis and ii) Energy Flow Analysis, both reflect socio-economic metabolism of a society with respect to material and energy flows respectively (Fischer-Kowalski & Weisz, 1999; Haberl, 2001a). Material Flow Analysis collects material data in the unit of metric tons and sums them up, whereas Energy Flow Analysis considers the energy value of flows in a socio-economic system with energy reported in gross calorific value (Krausmann et al., 2004). Furthermore, EFA methodology consider energy flows required for carrying socio-economic metabolism and differs from conventional energy balance by considering biomass in addition to biomass used for combustion (Haberl, 2001a). The addition of biomass to the energy flows provides insights into energy required to get work done by humans and animals, both of which are an integral part of an agrarian economy. EFA studies also provide the transitioning of economies from a renewable biomass based economy towards a non-renewable fossil fuel based economy.

MEFA has been developed by Eurostat with the help of Wuppertal Institute and Vienna SEC over last two decades to provide a comprehensive accounting framework (Eurostat, 2013). MEFA studies have been done on global, national and local level. Global studies mainly focused on resource scarcity and the consumption of materials (Matthews et al., 2000), whereas national and local studies were pivotal to understand resource use between different metabolic regime, namely the hunting and gathering, agrarian and industrial (Haberl et al., 2004). Hence both MFA and EFA provide a useful accounting framework to understand relationship between economy and environment by elaborating the bio-physical structure of society over spatial and temporal scale (Giljum, 2003; Haberl et al., 2004).

Derived indicators from MEFA provide information on resource use, disaggregated by four main material categories (biomass, fossil, metals and construction materials). It quantifies intensive indicators (extraction, imports, exports and consumption) which are correlated with extensive economic indicators such as GDP and unemployment (Kleijn, 2001). MEFA has been recognized in international agencies such as OECD, UNEP and EUROSTAT (UNEP, 2016; OECD, 2000; Eurostat, 2013). For global MEFA studies, collection of data in MEFA is primarily centered on the available statistics from international sources such as UNCOM, IEA and FAOSTAT. National databases are used for national economy wide MEFA (STACAN) and as we proceed towards sub-national level, the data gathering is done at primary or local level (Krausmann et al., 2004).

## 1.3 Biomass and Energy in a Global Context

Biomass is one the main inputs into the socio-economic system, comprising more than 33% of the global material consumption (Krausmann et al., 2008). Biomass is primarily used as term to describe food for humans and feed for livestock, and hence cannot be substituted for its primary purpose (Krausmann et al., 2008; Singh et al., 2012). Industrialized countries share of biomass consumption to total material consumption is approximately 25% whereas the developing countries account biomass as 2/3 of the total material consumption (Schandl & Eisenmenger, 2006). Besides food and feed, other uses of biomass are raw material towards infrastructure (forestry products) and as a source of technical energy (fuel wood) (Krausmann et al., 2008).

Even though biomass lost its share to other non-renewable materials such as fossils fuel, minerals and metals in the 20th century (Krausmann et al., 2009), the extraction of biomass from biosphere increased by 285% in absolute terms during the same period (Krausmann, Gingrich, & Nourbakhch- Sabet, 2011). Biomass consumption has increased by 100% in the last six decades (Schaffartzik et al., 2014). The major reasons for this increase has been rise in per capita income worldwide and change in dietary patterns. Increase has also been reflected in trade patterns as only the trade of agricultural biomass grew by three folds since 1960 (Mayer et al., 2015).

Also, the recent discussions of using biomass as alternate fuel to fossil fuels as a carbon friendly energy source (Berndes, Hoogwijk, & Van den Broek, 2003), has contributed to increase in biomass flows. Currently biomass contributes 9-13% of the technical energy supply of the world and it is expected that with increase in the use of biofuels, more pressure will be on the land to produce biomass (Lutz, Sanderson, & Scherbov, 2004). Increasing production causes more land and fertilizer use resulting in unwanted environmental impacts such as deforestation, biodiversity loss and groundwater contamination (Chabra et al., 2006). It is therefore imperative to analyze historical biomass flows for a sustainable transition in future biomass production and its effects to the biosphere (Soto et al., 2016)

Industrial revolution has brought a paradigm shift in the supply and demand of energy at the global level with a transition from solar-based biomass energy towards a non-renewable energy source based on fossil fuels. (Warr et al., 2010). The economic growth and development has provided transformative ways of energy conversion and brought changes in the way energy has been used historically (Podobnik, 2005). The energy requirement of society nowadays is 40 times more than the energy required in theory by humans for basic metabolism on a societal level, showing more energy consumed by infrastructure and services rather than humans themselves (Fischer-Kowalski & Haberl, 1998).

The requirement and technological advances has put fossil fuel energy at forefront which accounts for 82% annual extraction and supply of energy (IEA, 2017 ) with fossil fuel dominance and consumption increasing each year for the past few decades (Figure 1). The total combustion of fossil fuels in the 20$^{th}$ century which is approximated to be about 500 Gt with fossil fuels consumption increasing by 3.5% yearly (Krausmann et al., 2009) and predicted to increase by 113% more by 2050 for business as usual (Haberl , 2006). The increase in global consumption of fossil fuels i.e. from 8 billion tons in 1980 to 12.6 billion tons in 2009 (Giljum et al.,2014), has brought climatic changes in the world by the emissions of greenhouse gases (GHG) in the atmosphere.

Much of the energy analysis focuses only on technical energy including biofuels, which makes sense for energy policy, however for sustainability assessment it is useful to account for food and feed as mentioned earlier (Haberl et al., 2006). To understand socio-economic transition with respect to energy it is imperative that biomass be made part of energy flows with respect to technical as well food & feed energy (Haberl et al., 2004). In this study both biomass and technical energy will be considered as energy flows to understand the socio-economic metabolism of Canada as well as link of biomass and technical energy towards sustainable and environmental friendly energy production.

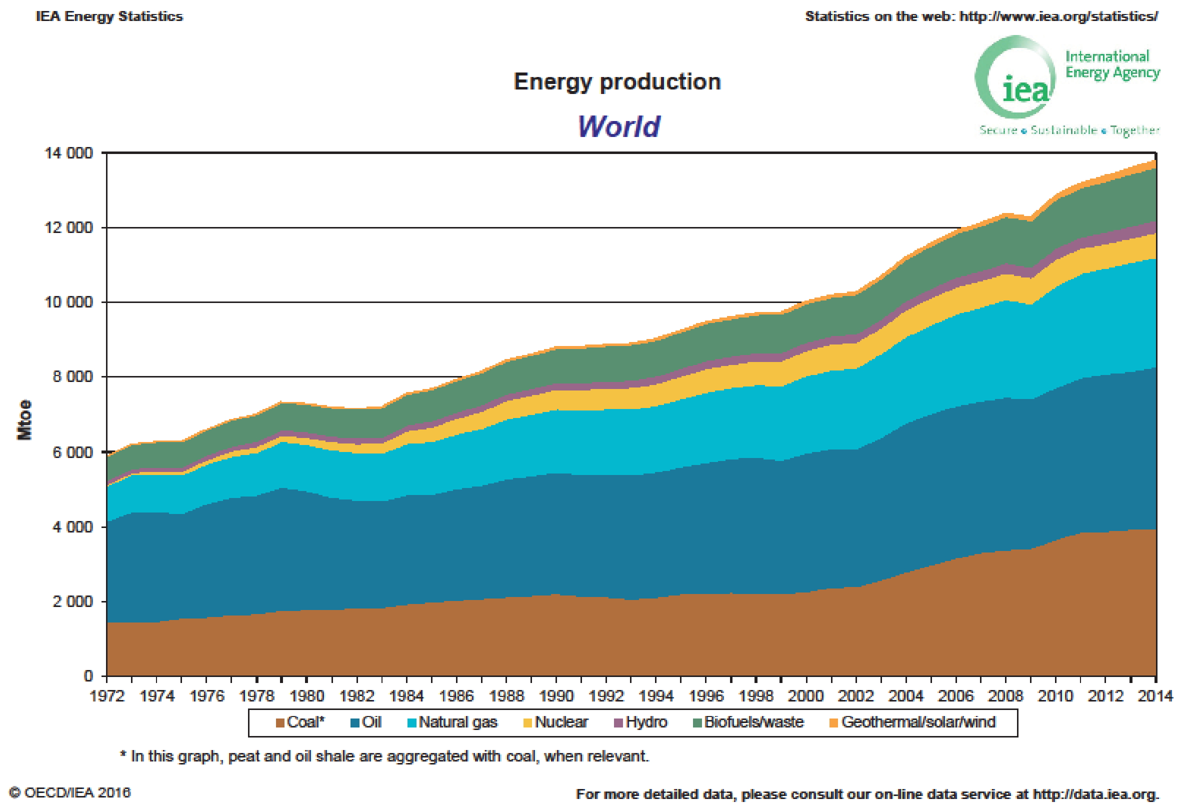


**Figure 1 Global Technical Energy Production from 1972-2014 (IEA, 2017)**

## 1.4 Biomass and Energy for Canada

Biomass consists of food for humans, feed for livestock, crops & forestry products for services, and energy crops & fuelwood for technical energy (Krausmann et al., 2008). Biomass holds a huge importance in Canadian economy as Canada produces 1.5% of the world's food (STATCAN, 2010) and consumes 0.6% of the total world food produced with only 0.5% of the world population. Canada produced 153.5 Million $m^3$ of forest round wood in 2014 (FAO, 2017) and ranked 7$^{th}$ in the world. Agriculture contributes to 8% of GDP of Canada (FCC, 2013) whereas forestry's share was 1.25% in 2013 (NRCAN, 2016). Being the 5$^{th}$ largest agriculture, third largest wheat and largest forestry product exporter, it is important to understand Canada's role towards global biomass production and supply.

Energy flows for Canada are as intensive as biomass flows are, since Canada ranks 6th in world's primary technical energy production and 8th in consumption (IEA, 2017 ). Being one of the largest exporters of crude oil and coal, the non-renewable fossil fuel amounts approximately 20% of the total Canadian exports by value (Statcan, 2012). The high production and export of fossil fuels has an adverse effect on Canada's commitment towards climate change. Since 1990 Canada's carbon emissions have increased by 20% which reflects heavy production and usage of fossil fuels (Figure 2).

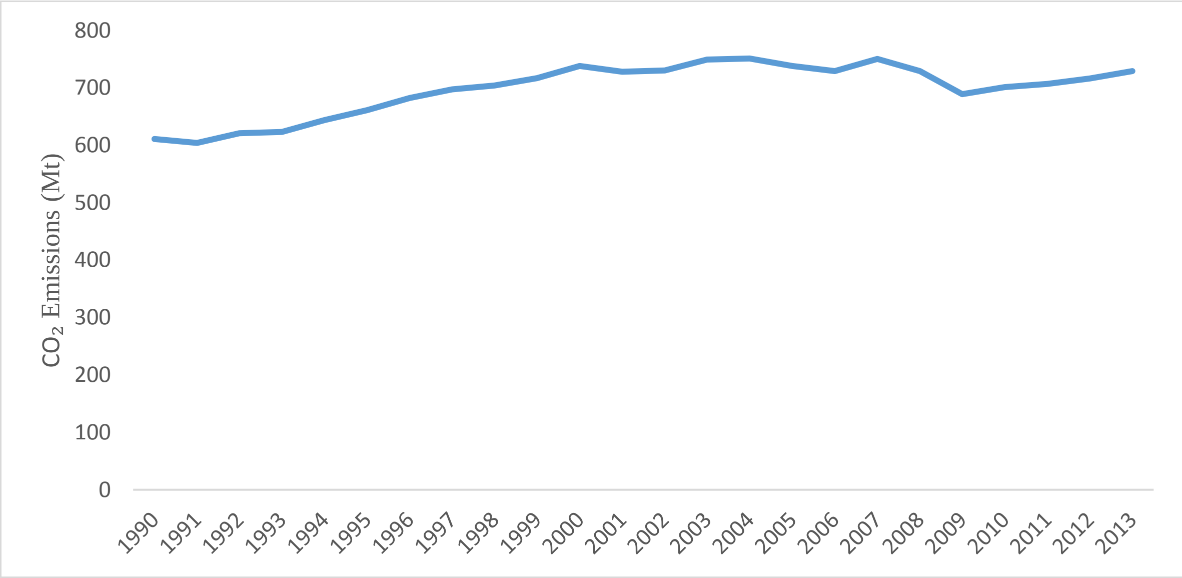


**Figure 2 Canada GHG emissions 1990-2013 (Government of Canada, 2017)**

Summing up the importance of biomass and energy flows of Canada, it is important to deep dive into the socio-economic metabolism with the tools of MFA and EFA to understand the role of Canada as a producer of biomass and energy as well as the historic values of these flows to disaggregated level such as to differentiate between crops, livestock and forestry in case of biomass and coal, crude oil, natural gas and renewable sources in case of technical energy. Also with the help of EFA the link between biomass energy and technical energy will establish key energy flows of Canada towards a sustainability transition.

## 1.5 Research Objective

The aim of this research is to study the biomass and energy flows for Canada for the time series of 1990-2011. Using the Material and Energy Flow Analysis (MEFA) approach consistent with Eurostat guidelines and methodology, the analysis incorporates both technical energy and biomass flows to calculate biomass and energy metabolism of Canada. The data reflecting biomass incorporates the food, feed, forestry and other uses such as tobacco, and the data for technical energy comprises renewable and non-renewable energy sources. Following are the specific research questions addressed in this study:

i) How has the metabolic profile of Canada changed over time?

ii) How does Canada compare to other nations such as US in terms of biomass and energy use?

iii) Where are potentials for a sustainability transition in biomass and energy sector?

## 1.6 Thesis Structure

This thesis aims to understand the socio-economic metabolism of Canada with respect to Biomass and Energy flows using the MFA and EFA methodology for the time series of 1990 to 2011. The thesis is further divided into four chapters i) chapter 2 is the literature review that has been produced on socio-economic metabolism, its origin, development of methodology and recent empirical analysis for both material and energy flows, ii) chapter 3 explains the methodology, data collection and explanation of indicators for both biomass MFA and energy EFA, iii) chapter 4 outlines the key results from the study and a comparison of these results with results from United States and lastly iv) chapter 5 discusses the key outcomes from the results and looks at how the socio-economic metabolism of Canada has been changing over the analyzed time period. Chapter 5 further looks at the prospects for a sustainability transition of Canada and gives a summarized conclusion.

# Chapter 2 Literature Review

## 2.1 Introduction

This literature review offers an overview of the development of the term metabolism from natural science to social science and towards the current state of socio-economic metabolism by using material and energy flow analysis. It summarizes the research on Material and Energy Flow Analysis (MEFA) as well as the usefulness of MEFA in understanding material flows.

## 2.2 Social Metabolism

Metabolism in text books of biology is defined as "to sustain the process of life, a typical cell carries out thousands of biochemical reactions each second, the sum of all biological reactions constitute metabolism" (W.K, 1992). The process of metabolism in living things carries out systematically where raw material is obtained from environment and converted into useful energy and building block for the organism. In the case of human beings, the term metabolism needs to expand to include interactions human beings create amongst themselves and with the environment. This creates a different form of metabolism for the social science theory.

Sustainability is a problem of society-nature interactions, where society extracts and inputs resources from the nature, processes those resources and emits output to the nature (Fischer-Kowalski & Weisz, 2016). This has caused long-term sustainability problems of resources scarcity, extraction of non-renewable resources at the input side of the social system and receiving outputs by nature of waste and pollution due to industrial processes. Thus, the emphasis for sustainable development is to consider the interface between society and nature for flow of materials and energy i.e. social metabolism (Fischer-Kowalski & Weisz, 1999).

The term metabolism in social science was first used by Marx (1867) in the nineteenth century. They describe social metabolism as use of labor processes by man to interact with nature to fulfill human needs. Further research added to the concept of social metabolism such as by Wilhelm Ostwald in 1909 where he used second law of thermodynamics to argue that the reduction in the loss of free energy is the objective of human cultural development (Fischer-Kowalski, 1998). Prion to Ostwald, Geddes in 1884 developed an empirical formula using input-output analysis for the first time in social metabolism where he identified energy and material losses in the different stages of producing a product (Geddes, 1884). However, these theories and analogies remain largely irrelevant in the modern sociology where environment is not referred to as the physical attributions of the nature but as the social ones (Duncan, 1959). Ayres & Knees (1969) argued that all input to production processes should be completely converted into an output and that the output should be consumed with no waste remaining. They considered the environmental impact as a material balance problem and correlated the social system to ecosystem where any residue is treated as a burden to the system.

To undestand the social-nature interaction, there are different frameworks provided by researchers over last few decades.  Fischer-Kowalski & Weisz (1999) discuss three major frameworks which are Boyden’s human ecological model, Godelier’s society-natural interraltions as a driving force of social change and Sieferle’scomplex system and cultutal evolution. Other frameworks include Ostrom’s social ecological system (SES) framework, Frankfurt’s approach to social ecology and Dutch societal transitions management school (Fischer-Kowalski & Weisz, 2016). In this thesis focus will be on framework for social-nature interaction developed by Vienna social ecology school and discussed in detail by Fischer-Kowalski & Weisz (1999) and Fischer-Kowalski & Weisz (2016)

Fischer-Kowalski & Weisz (2016) provide a conceptual framework of social-natural system interaction with respect to history, current human development and a possibility of sustainbaility tansition in future. The framework distinugishes between nature and culture, where natural sphere represents material world and cultural sphere is subjective to recursive communication (Figure 3). The intesection between the two spheres encompasses human society which comprises culture as well as elements of the material world, thus demonstrating human society as a hybrid of both realms.

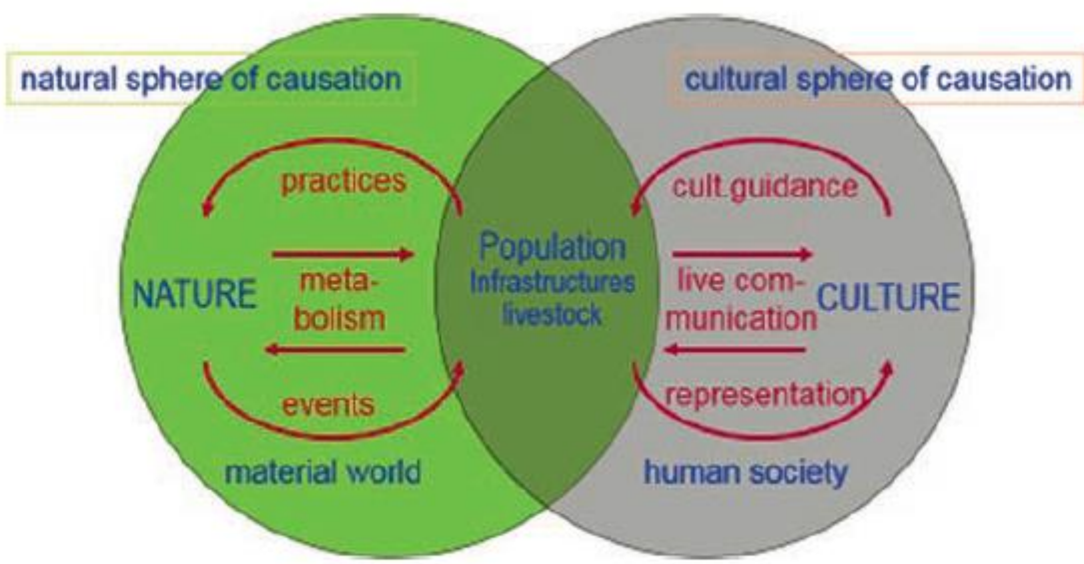


**Figure 3 Conceptual model of society-nature interaction developed by the Vienna Social Ecology School (Fischer-Kowalski & Weisz, 2016)**

Interfacing a society with its natural environment creates a socio-ecological system (Haberl et al., 2004). The overlap of culture and nature results in biophysical structures of society which contains human population, livestock and man-made infrasturcture (Figure 3). The interaction of socio-economic factors such as monetary flows with biophyical stock and flows has to be analyzed to answer complex questions of human activity towards ecolgical degradation. A causal relationship between nature and culture to develop biophysical structures of the society shows the dependence of human society on symbolic communication and flows of material & energy (Fischer-Kowalski & Weisz, 2016).

The socio-ecological systems links to different modes of subsistence for humans throughout the world history. These modes can be categorized in three major types i) hunter and gatherer, ii) agrarian and iii) industrial regimes (Singh et al., 2010). Transition from one regime to the other over a period can bring about challenges to sustainability such as climate change, resource scarcity, loss of biodiversity, etc. (Haberl et al., 2004). The Neolithic revolution which is the transition from hunter & gatherers to agrarian society, and the Industrial revolution which is the transition from agrarian economy to an industrialized one, portray unique factors of socio-economic metabolism and hence sustainability challenges. Haberl et al (2004) summarized the socio-economic metabolism aspects of each regime, the human induced changes in the eco-system and sustainability challenges (Figure 4)

| Mode of subsistence | Socio-economic metabolism | Colonization of natural systems | Human-induced changes in ecosystems | Challenges to the continuation of this social-ecological regime ("sustainability problems" |
|---|---|---|---|---|
| Hunter-gatherer | "Uncontrolled solar energy system" based upon extraction of biomass from (more or less) natural ecosystems | None, or not important | No large-scale human-induced changes in ecosystems, probably except for fire used in hunting and possibly human-induced extinction of animal species | Extinction of important prey species (no matter whether this was caused by human activities or by natural changes or both) |
| Agrarian society | "Controlled solar energy system" based upon biomass extracted (mostly) from (colonized) agro-ecosystems | Colonization of terrestrial ecosystems ("land use")<br>Domestication of animal and plant species | Pervasive changes in patterns and processes of terrestrial ecosystems caused by colonization on regional scales, but globally more or less negligible | Balance between population, territory and efficiency of the land-use system<br>Maintenance of a positive energy return on investment of agriculture |
| Industrial society | "Fossil energy system" based upon area-independent, highly concentrated energy sources (fossil fuels, nuclear energy, hydropower, etc.) plus biomass (mostly) from agro-ecosystems<br>Large-scale extraction of metals and minerals from geological deposits | As agricultural society, but with qualitatively different means, plus efficient methods for colonizing interventions into biological systems on all hierarchical levels down to the genome | Global changes in biogeochemical cycles (carbon, nitrogen, etc.) and the climate system (temperature, precipitation, extreme events), massive depletion of the Earth's biodiversity and genetic resources, large scale soil erosion | Depletion of the resource base upon which the society's metabolism is based<br>Necessity to cope with accelerating changes in the global ecosystem<br>Declining resilience of ecosystems due to biodiversity loss |

**Figure 4 Selected aspects of socio-economic metabolism, colonization of natural systems, changes in ecosystems and sustainability of hunter–gatherers, agrarian societies and industrial societies (Haberl et al., 2004)**

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To understand the drivers of transition from one to regime to the other it is important to analyze social metabolism of a society. The concept of social metabolism is portrayed as a tool to analyze social-nature interactions. This is described by Singh et al (2010, page 63) in the following passage

"concept *is based on the premise that any social system not only reproduces itself culturally but also biophysically through a constant flow of materials and energy with its natural environment as well as with other social systems. The size of flows is intricately linked to the biophysical* *stocks of the social system and determined by the sociometabolic regime it belongs to: every sociometabolic regime has a different metabolic profile, i.e. quantity and quality of materials and energy used*"

Growing social or industrial metabolism has been the main reason for environmental impact caused by humans (Krausmann et al., 2009). Socio-economic metabolism is characterized as a continuous process which involves conversion of raw materials for products and services by society, and ultimately into emissions and waste (Krausmann et al., 2009; Schandl, & Schulz, 2002; Ayres & Simonis, 1994) in a similar way to that of ecosystem (Fischer-Kowalski & Haberl, 1998). The concept of socio-economic metabolism has been largely used to describe the changes in the material and energy use of the society towards development (Krausmann, Gingrich, & Nourbakhch-Sabet, 2011). Analyzing a socio-economic system and its metabolism provides insights to society's relation with the nature and the scope of that relation (Fischer-Kowalski & Haberl, 1998) to understand the change to undergo industrialization (Krausmann, Gingrich, & Nourbakhch-Sabet, 2011). Transition from agrarian to industrialized society is demanding more material use from the developing economies (Schaffartzik et al., 2014) causing sustainability problems with respect to resource constraint and over-limit of ecosystem's absorbing ability for wastes and emissions (Schandl & Schulz, 2002).

## 2.3 Material Flow Analysis

MFA is an accounting framework for analyzing biophysical aspects of a socio-economic system. It provides "an aggregate overview, in tons, of annual material inputs and outputs of an economy including inputs from the national environment and outputs to the environment and the physical amounts of imports and exports" (Eurostat, 2001a). MFA is simple model of economy embedded into environment and is considered an open system for material and energy flows entering and leaving it (Singh & Eisenmenger, 2010). MFA is based on first law of thermodynamics i.e. matter or energy is neither created nor destroyed but only converted into a different form (Weisz et al., 2001). The law of conservation allows the system to understand the inputs from environment to the economy (natural resources) and the output from economy to the environment (waste) as well as the material which is accumulated in the economy. (Eurostat, 2001a).

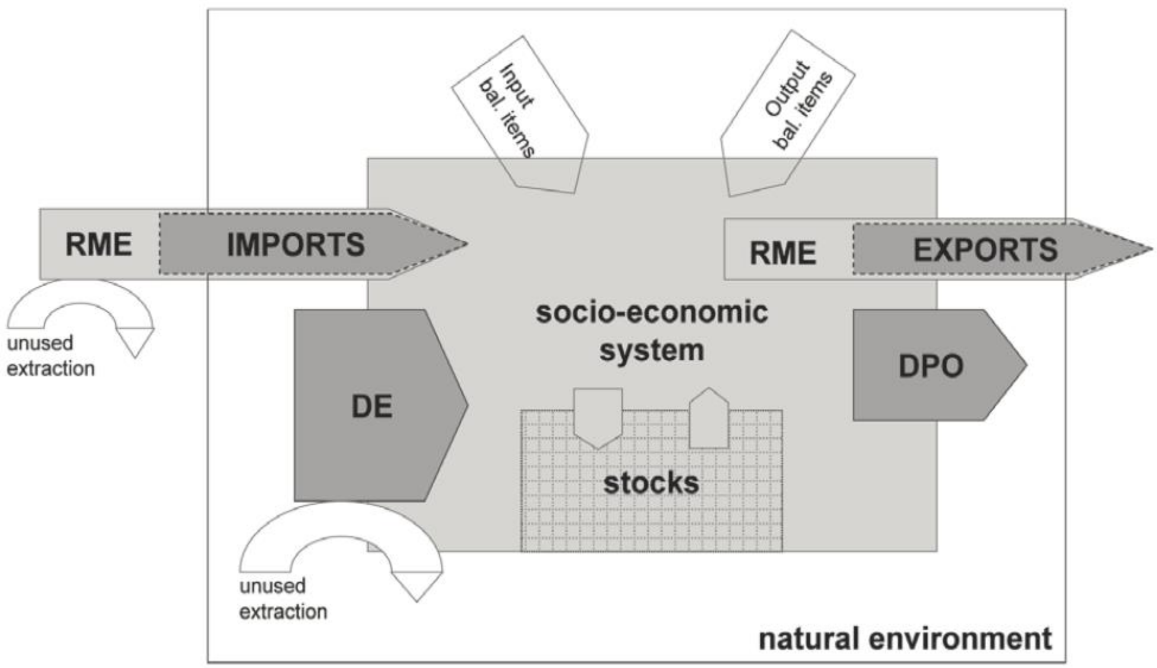


**Figure 5 Schematic representation of MFA (Singh & Eisenmenger, 2010)**

The MFA accounting concept can be put into words in the following way:

***input = output + additions to stock – removals from stock***

***= output + net stock changes***

The material accumulated in the system are referred to as stocks whereas materials which are required to maintain these stocks are known as material flows (Fischer-Kowalski et al., 2011). The stock accounted in MFA is based on three main categories a) human population i.e. materials used in continuing human ppopulation with required material security b) infrasturucture built by humans to carry out economic activities and lastly c) livestock and other domestic animals with economic value (Fischer-Kowalski et al., 2011; Matthews et al., 2000). In MFA studies only the flows which cross the system boundary on input and output sides are counted. The hidden flows such as livesock prodcuts (milk, meat) are considered internal transfers and thus are not part of data sets(Fischer-Kowalski et al., 2011). The material flows are classified in three main types: air, water and materials (Fischer-Kowalski et al., 2011). Due to the high amount of usage of air and water, researches are required by methodology reviews to keep these seprated from the accouting of material flows (Eurostat, 2009). The materials are thus further classified into biomass, fossil fuels, industrial minerals and metal ores, and bulk materials for construction categories (Krausmann et al., 2015; Fischer-Kowalski et al., 2011).

The primary aim of an MFA account is to present socio-economic activities in physical quantities, which makes MFA accounts compatible to System of National Accounts (SNA) (Singh & Eisenmenger, 2010). MFA also provides insight for making policy, defining targets and evaluating performance of the society by integrating environmental and economic indicators. In addition to record physical quantities of the material flows, another usefulness of MFA was the biophysical indicators it introduced which were required to monitor progress towards sustainability.

The accounts are compiled in tonnage per year and with the derived indicators, helping us to understand input flows, output flows and stocks within the system boundary of an economy (Krausmann et al., 2015). The system boundary is defined in two terms i) as a crossover between socio-economic system and the natural environment and ii) the political front i.e. the trade with other economies (Fischer-Kowalski et al., 2011; Krausmann et al., 2015). The indicators used are divided into two main flows, the input flows and the output flows. Input flows are  Domestic Extraction (primary production from within the economy) and Imports(flows from other national economies). Together these constitute the Direct Material Input (DMI) (Krausmann et al., 2015; Fischer-Kowalski et al., 2011). The output flows are divided into domestic processed output (DPO) and exports from the economy. The difference between the input and output flows provide us the net addition to stocks to the economy in physical terms(NAS).  Another important disctinction in input flows is the used and unused extraction. The used extraction is the material which contribute to the economy, whereas the unused extraction is the extraction of material done without any economical benefit such as waste from mining and wood harvest (Fischer-Kowalski et al., 2011; Eurostat, 2009). The indicators will be discussed in more detail in chapter 3 of the thesis.

### 2.3.1 Historical development of MFA

Wolman (1965) described material input, storage, and output for a hypothetical U.S. city with one million inhabitants, stressing upon the waste and residues from the processes of the city's metabolism. He laid down the foundation for urban metabolism in the modern sense. Building upon that Boulding (1966) treated the urban society as an econosphere by comparing it to an input-output system within the biosphere. Ayres and Knees (1969) were the pioneers in modelling MFA. They argued that all production processes are to work in such a way that an input completely converted into an output and that the output consumed with no residue remaining. They considered the environmental burden as material balance problem and correlated the social system to ecosystem where any residue treated as disservice to the system. This started the research tradition to quantify the energy and material flows in industrial economies. It not only provided a conceptual framework but an empirical framework as well. This form of MFA has been adopted more rigorously in 1990's where MFA studies were more linked to the sustainable development of the cities (Fischer-Kowalski, 1998).

EUROSTAT in the 90s started using MFA data to represent the environmental metrics following by a guide to explain the methodology of MFA of indicators (Eurostat, 2001a). However, the (Eurostat, 2001 b) and (Eurostat, 2001a) lacked specific information regarding the compilation of MFA data (Krausmann et al., 2015). The Eurostat (2002) further elaborated on the MFA indicators for EU-15 as these indicators became a part of Eurostat Environmental Statistics. In the next few years, the MFA division of Eurostat worked towards the standardization of MFA methodology, data compilation and standard tables for EU states (Krausmann et al., 2015) reflected in MFA compilation guidelines by Eurostat (Eurostat, 2007; Eurostat, 2009; Eurostat, 2012; Eurostat, 2013).

The Organization for Economic Co-operation and Development (OECD) also played an integral role in the MFA research with several workshops and publications to further standardize the methodology of MFA accounting (Fischer-Kowalski et al., 2011). Carrying on these lines, a recent working paper guide has been developed by (Krausmann et al., 2015) to document the conceptual framework and methodological standards adopted for MFA research as well as providing thorough procedures to compile material flow data accounts on the international level.

### 2.3.2 Empirical studies using MFA

MFA national accounts were first started done for Japan, Germany and Austria. The work done formed the first national level material flow database (Fischer-Kowalski et al., 2011). WRI then published two reports for MFA in span of three years focusing on material input of four major economies of the world i.e. Germany, Japan, Netherlands and United States for the period of 1975-96 (Krausmann et al., 2015) as well as the outputs of the same four major economies plus Austria for the same period (Matthews et al., 2000). Similarly the output representation in the second report by (Matthews et al., 2000) presents an increase in the Domestic Processed Output regardless of the GDP growth for all major economies. DPO per capita generated by countries is calcualted over the period of 1975-1996, displaying that an average person wastes more in 1996 than what he used to waste in 1975. The resource consumption and consequently the environmental damage being caused by the major economies was evident from these two reports where US was found using around 20 Billion Metric Tons of materials per year. A similar metabolic profile was found for other economies as well.

These studies provided the platform for researchers to use the MFA methodology to further analyze material flows of other economies as well as on a global scale. The need for conducting MFA accounting at a national level arises more as industrialization is happening rapidly around the world. Furthermore, assessing the relationship between the economic activity and environmental degradation is necessary to dematerialize industrial economies.

Studies on global as well as on national scales were conducted by researchers in the past decade. The number of studies is continuously on the rise considering the increasing requirement of material by industrialized countries to maintain its stocks and by the developing world to build stocks as shown in the first global material estimate (Schandl & Eisenmenger, 2006). Schandl et al (2006) linked development with material extraction as industrialized countries had high material extraction per capita and high population densities which caused them to use their land intensively.

The material consumption by human population increased approximately 10 times more at the start of 21st century than at the start of 20th century i.e. over the span on 100 years (Krausmann et al., 2009). Material consumption is still increasing at a rate of 3.4% per year and posing a major threat to resource productivity. The unequal distribution of materials across the globe provides insights into resource usage by developed countries. This disparity is as high as a factor of 20, with 15% of the global population responsible for approximately half of the global material resources extracted (Schaffartzik et al ., 2014).

The transition of material use changed rapidly within the 20th century from biomass being a large share in the first 50 years of the century and after 1950 (in the post-World War II scenario) a fast increase in metals, mineral ores and fossil fuels extraction showed the rapid industrialization of the world (Schaffartzik et al., 2014; Krausmann et al., 2009). Furthermore, the resource extraction and consumption over the past 30 years have increased by 94% and 2 tons per capita respectively (Giljum et al., 2014).

The work on global studies encourages the academia to further dig deep on national and sub national levels. To understand the global industrial metabolism, the metabolic profiles of regions and national economies is required to put further emphasis on sustainable resource use

(Schaffartzik et al., 2014). Studies were conducted to understand over a long-term the metabolic transition in material use resulting in socio-ecological regime transition in Austria, United Kingdom, United States and Japan (Krausmann, Schandl, & Sieferle, 2008; Gierlinger & Krausmann, 2012; Krausmann, Gingrich & Nourbakhch-Sabet, 2011).

MFA studies also gave insights into socio-technical system and resource consumption for developed countries such as in Australia impacting sustainable resource use (Schandl et al., 2008). Furthermore, the MFA methodology reflects ongoing transition of developing countries from agrarian to industrial economy such as for India (Singh et al., 2012), and other developing nations for example for Uzbekistan (Raupova, Kamahara, & Goto, 2014), Czech (Kuskovaa, Gingrich, & Krausmann, 2008) and Estonia (Oras & Grüner, 2010).

From national and global scale, MFA expanded in recent years to local level where local is referred to a sub-national or regional scale. This granularity can mean a province, city or an entire small county. These studies include investigation of Sang-Seng village by Grünbühel et al (2003), social metabolism of Nicobar Islands by Singh & Haas (2016) , material metabolism of Tat Hamlet in Vietnam (Schandl, Hobbes, & Editors, 2006), society-nature interactions in Sierra Madre forest region in the Philippines (Hobbes & Kleijn, 2007) and Campo Bello, Bolivia at the Amazonia by Ringhofer (2010). This thesis focuses mainly on national biomass and energy flows of Canada. Furthermore this study doesnot include local studies in its scope and the therefore details of local studies are not discussed.

Such studies have given insights on various kinds of economies such as developed nations like the United States, developing nations like Czech and agrarian economies like India. The urge of development requires more material use and therefore to ensure resource sustainability, it is important to understand the flows and project the future national and global needs based on the material consumption of the world as well as the sustainable policy development.

### 2.3.3 Biomass Flows

This study focuses on the biomass and energy flows of Canada; therefore, it is important to understand questions asked in the literature with respect to biomass flows of other economies in the material flow accounts and to relate with them accordingly. Since the initial account for biomass of a national economy by Kneese & Colleagues (1974), much has been done by the MFA community to conceptualize and quantify biomass flows over global and national scale (Fischer-Kowalski, 1998). The pioneering report of material flow accounts by Adriaanse et al (1997) provided biomass accounts for 1991 of US, Germany, Netherlands and Japan followed by biomass account for Austria by Schandl, H (1998). Both these reports focused on decoupling of economic growth and environmental impacts caused by extensive use of biomass such as soil erosion impacting soil fertility and water pollution.

The first acknowledged global account of biomass flows using the MFA methodolgy was presented by Schandl et al (2006) for the year 1999, covering 225 countries. Schandl et al (2006) concluded that other than environmental pressure on land such as soil erosion and deforestation, high biomass extraction can lead to biodiversity loss. Comparing industrialzed countries to developing countries, biomass was a dominant material extraction i.e. 70% of the total extraction for developing countries for the year 1999. Schandl et al (2006) also pointed out the increasing use of fossil fuels for energy purposes is gradually replacing biomass, the traditional source of energy.

Weisz et al (2006) regards biomass to be irreplaceable as human food and determines the extraction phase of biomass of large enviornmental reference in cross-examination of EU-15 for material flows. This study further established the notion that biomass being an area dependent material is related to population density and can act as a limiting factor for building system stocks. Similarly, local climatic conditions and technological advancement can alter the productivity yield. Weisz et al (2006) also provided the relation between high livestock number and high biomass extraction i.e. economies with high number of livestock need to produce more fodder to cater for animal feed. This relation however can be offset by trade where countries can import fodder to fulfill animal feed requirement. Furthermore with the biomass flow account, it was observed that countries with low biomass per capita value for extraction and consumption have intensvie production system and can pose major environmental pressure on land.

Krausmann et al (2008) provided a comprehensive account of global biomass flows with respect to production, trade and consumption. This study provided further breakdown of biomass flows in food, feed, fibre and energy use by further qunatifying grazed biomass by livestock, calculation of crop residues and unused biomass flows (for example biomass wasted during harvest). This study qunatified that 58% of the total used biomass flows were extracted for livestock, 12% for human feed, 20% as raw material to other products and 10% as firewood. Regional variations of biomass used by Livestosck were found to be from 30-75% and are explained by livestock used as workforce or feed. Krausmann et al (2008) also connected the availability of land and productivity with the harvest and consumption of biomass in absolute and per capita terms. Other factors such as livestock density, trade and affluence also affect patterns of biomass extraction and consumption.

Steinberger et al (2010) enahnced on usage of biomass by analyzing biomass as a subsitution for fossil fuels and debating upon the coupling of biomass to economic development, unequal distribution, biodiversity loss and resource scarcity. Krausmann et al (2009) further supported the notion of environmental degredation in the manner of soil errosion, deforestation, ground water depletion and biodivesrity loss due to increased biomass extraction and land use intensity. Giljum et al (2014) linked increasing biomass extraction and consumption to water scarcity on a global level with water intensive production whereas Schaffartzik et al (2014) presented the share of biomass decreasing to the share of fossil in the global material flows for industrialized countries (Figure 6).

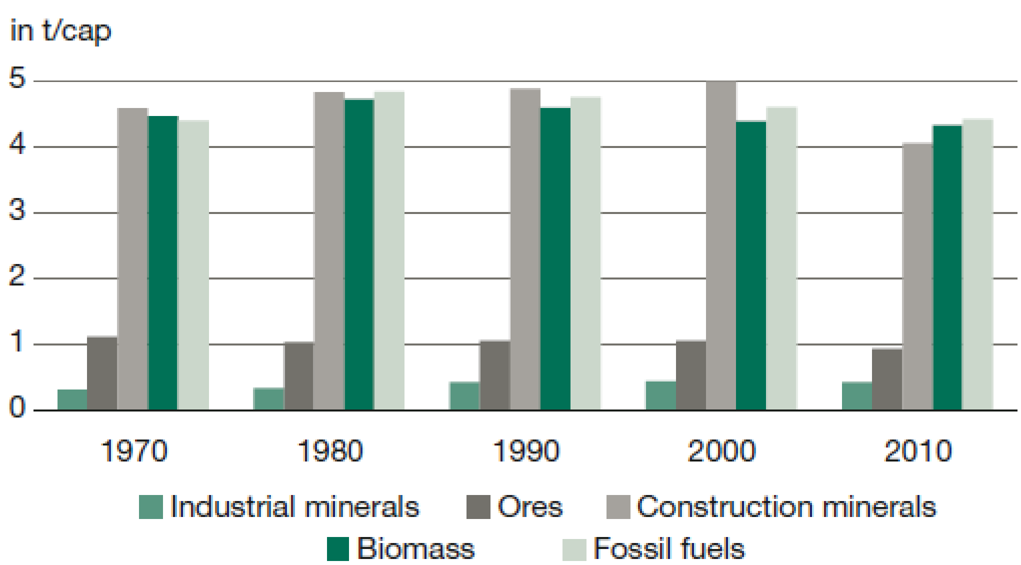


**Figure 6 Material use by category in the Industrial countries (Schaffartzik et al., 2014)**

National studies on biomass flows provide a step further into analyzing biomass extraction, trade and consumption trends on an individual economic level for both developed and under-developed countries. The metabolic transition from 19th century to 21st century for US, United Kingdom, Japan, Australia and Austria show the same tranisiton from agrarian to mature industrial socio-ecological regime with considerable decrease in share of biomass in material and energy flows of the society despite increase in the growth of biomass extraction (Gierlinger & Krausmann, 2012; Krausmann, Gingrich & Nourbakhch- Sabet, 2011; Krausmann, Schandl & Sieferle, 2008; Schandl et al., 2008). All these studies show the trajectory of developed countries over a time series of past 200 years, which seemed to have solved the problem of limited economic development but at the expense of environmental degredation, biodiversity loss and climate change. Schandl et al (2008) provides a picture of Australian agriculture which is facing soil degradation, water salinity, habitat damage, extinction of local vegetation and growth of weeds due to excessive use of fertilizer. Political changes also affect the biomass metabolic profile as seen in the case of USSR, the economy was net importer of biomass before the collapse and after the formation of Russian federation it became net exporter of biomass even though the consumption and extraction of biomass continued to grow (Krausmann et al., 2016). Singh et al (2012) examines the biomass system of India as a developing economy and points out the factors which determine biomass flows. These patterns include the dietary habits as Indian diet include less meat hence providing an efficient production system. However despite consuming less meat, 60% of the total biomass extraction is used for animal feed where livestock is used for domestic help and its manure as fertilizer.

Analyzing the national studies on biomass flows, it is evident that biomass flows depend on a number of factors such as population growth, land intensity, trade, dietary habits, political scenarios, social customs and energy requirement of the society. It is important to understand the biomass flows in the relation of sustainability problems which a system can face, where these problems can relate to environmteal degradation, resource scarcity, biodiversity loss and climate change.

## 2.4 Energetic Metabolism and Energy Flow Analysis

The focus of this research is specifically on biomass and energy flows of Canada over the time scale of 1990-2011. Biomass flows have been covered in the global and national MFA studies (Krausmann et al., 2009; Giljum et al., 2014), and are accounted in the similar way as per the methodology of Eurostat (Eurostat, 2009) and (Krausmann, et al., 2015). However, to consider the energetic flows of the societies, they need to be compatible with current MFA methodology (Haberl, 2001a). Energetic flows and material flows of an economy are linked in many ways. To build infrastructure stocks energy is required to fuel transport and provide drive to the transformation of material from one form to the other. Energy can be used to increase material throughput (agricultural yield) as well as decrease material extraction (e.g. recycling) (Haberl, 2001a). Similarly use of material can also reduce energy requirement of the societies (e.g. through better insulation in walls) (Nishioka, Yanagisawa, & Spengler, 2000). On the other hand, there are scenarios of waste material providing energy, contributing to improve both problems simultaneously (Haberl & Geissler, 2000).

Keeping in view the interdependence between the two entities, a society’s true metabolism needs to be accounted for by broadening the horizon by incorporating the energy demand and consumption of societies along with the material requirement. Furthermore, one of the most important purposes of carrying out an MFA is to link the material flows to environmental impacts created by the extraction and consumption of materials. Using energy flows in the study provides a reflection of energy related environmental and social problem associated with both renewable and non-renewable sources of energy (Haberl, 2001a). However, to know the energy flows of a system, it is important to know the methodology to account for them and for this reason we have a methodology to generate material flows.

The conventional energy balances and statistics have been developed keeping in mind the energy use towards the economic development of a system (Haberl, 2001a), which shows that human ecology and environmental impact accounting was not part of the cause to develop the tool of energy balance (Figure 7).

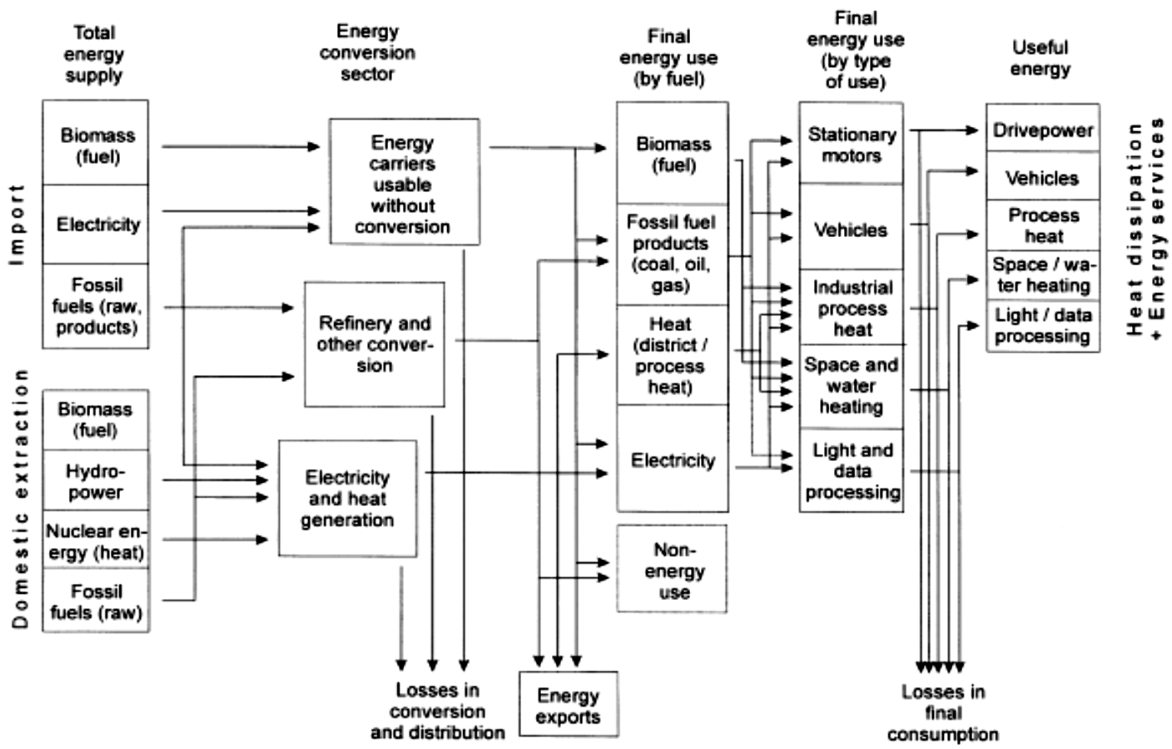


**Figure 7 Energy flows usually covered in national energy balances (Bittermann, 1999; IEA, 1995)**

In an overview Figure 7 describes the flow of energy for technical processes for which fosil fuels, hydropower and nuclear energy undergo transformation from energy input, energy conversion to final energy and useful energy form (Bittermann, 1999; IEA, 1995; Haberl, 2001a). In addition to these flows in the late 90s, countries also started taking interest in the renewable energy such as solar energy as part of their national energy balances (UN, 1997). The emphasis of countries on energy balance and technical use of energy, points out the use of these energy flows primarily for economic activity rather than the socio-ecological and environmental analysis of the system.

The purpose to carryout metabolism studies is to align the analysis and usefulness of results between the aspects from natural sciences and social sciences such as economics and ecology (Haberl, 2001a). To follow a metabolism approach in the context of energy flows of the society, it should consider human society as a complete ecosystem both with respect to physiological energy flows and technical energy flows. Following the metabolism approach, hence allows for determining energy flows in every detail. The energy balances as presented in Figure 7 do not consider the nutritional energy for both humans and animals as well as energetic value of material which build up societal stocks e.g. timber used in the construction of a house. Since the traditional energy balances focuses on energy required to maintain only stocks related to infrastructure, a complete energetic metabolism approach must include the energy required for humans and domesticated animals (Haberl , 2001a).

Haberl (2001) emphasizes that to be consistent in accounting for energy flows; it is favorable to count all energetic materials in terms of their gross calorific value (GCV) rather than the net calorific value (as fossil fuels are represented in NCV). GCV differs from NCV in a way that it not only accounts for the usable energy in the material but also for latent heat of water vapor. Biomass i.e. food and fodder is generally represented in GCV to maintain consistency in data compilation and analysis. Energetic metabolism requires the technical energy to be represented in GCV as well. Calculations based on GCV provide comparison between technical drive power and human/domestic animal drive power. Though in modern day the technical drive power supersedes the human plus animal drive power but in comparison over centuries i.e. transition of society from hunters & gatherers to agricultural society and finally to an industrial one, it is necessary to include all types of drive power (Haberl & Geissler, 2000; Haberl,  2001a).

Keeping in view the MFA notions, Energy Flow Analysis (EFA) has been explained in the same way by Haberl (2001). To compliment Direct Material Input (DMI), an indicator of Direct Energy Input has been proposed (DEI). DEI incorporates domestic extraction (DE) and imports of both biomass and fossil fuels. Both the biomass and fossil fuel flows are expressed in their gross calorific value for consistent comparison (Figure 8). Also, Haberl et al (2011) explains the importance of hidden energy flows, which constitute of final and useful energy with in the society to calculate total primary energy input. This is not within the scope of this study but can be referred (Haberl , 2001a).

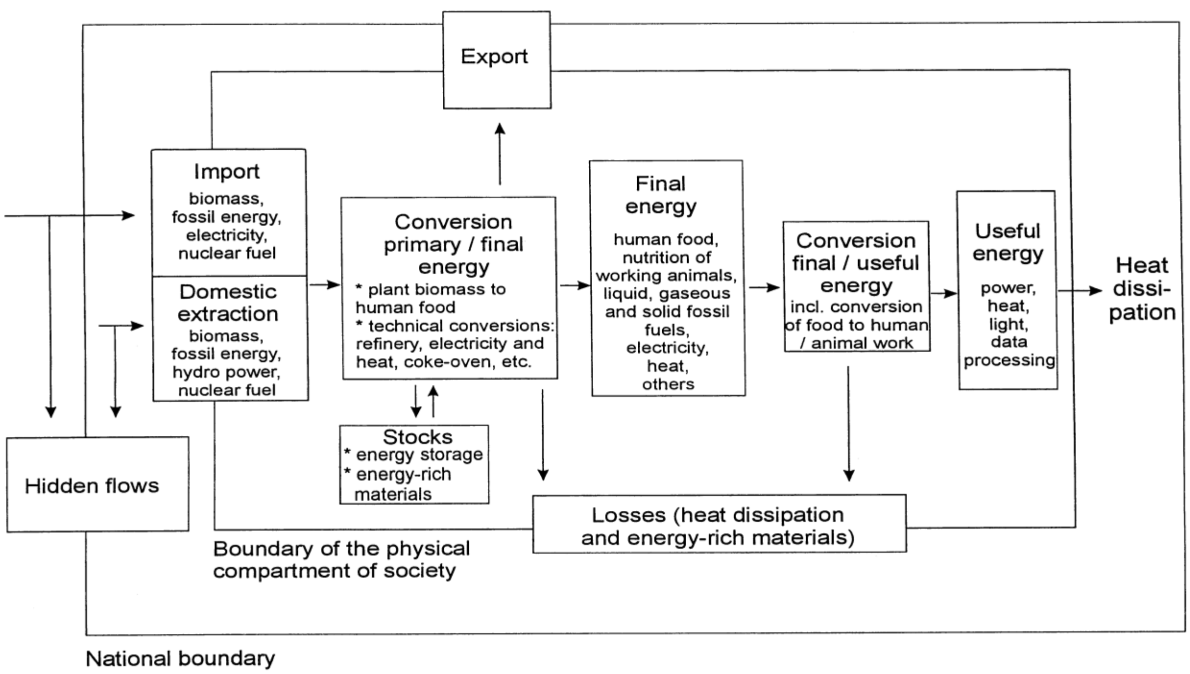


**Figure 8 Summary of the proposed methodology (Haberl , 2001)**

### 2.4.1 Energy Flow Analysis Empirical Studies

Studies have been published sicne the 19th century towards sustainable development keeping in view the energy metabolism and transition of society from agrarian to industrial regime (Haberl, 2001b). Energy statistics and Energy balances are nowadays readily available to analyze and form policy upon, for example IEA statistcs and energy balance data is published for well over 130 countries since 1990 to date (IEA, 2017 ). However research on MFA in recent years has overshadowed the energy flows and keeping that in view we shall review the empirical studies based on the methodology proposed by (Haberl , 2001a).

Haberl (2001 b) has provided the first of EFA study comparing three different types of societies i.e. hunters and gatherers, agrarian society and industrial regime (Table 1).

**Table 1 Comparison of three different modes of subsistence Haberl (2001 b)**

| | *Total energy input* | | | | *Domestic consumption* | | | |
|---|---|---|---|---|---|---|---|---|
| | *Total (GJ/cap·yr)* | *Biomass (%)* | *Fossil (%)* | *Others (%)* | *Total (GJ/cap·yr)* | *Biomass (%)* | *Fossil (%)* | *Others (%)* |
| Hunter-gatherers | 10 | 100% | 0% | 0% | 10 | 100% | 0% | 0% |
| Sang Saeng 1998 | 76 | 93% | 7% | 0% | 45 | 91% | 8% | 1% |
| Austria 1995 | 251 | 33% | 58% | 8% | 196 | 32% | 60% | 9% |

According to the values of GJ/cap, it is clear that to move from a hunter & gatherer society to an agrarian one to the industrial economy, it is imperative that the dependence of soceity becomes more on fossil fuels than solar dependent biomass. The breakup of DEI of Sang Saeng (Table 1) provides 95% of the energy input was biomass i.e. 48 GJ/cap off total 53 GJ/cap where the rest of the energy being imported as fossil fuels. Also 70% of the total energy was being consumed as fodder for animal to provide drive power for the economy. Surprisingly, Austria in the 19$^{th}$ century had the same metabolic profile and it can be contemplated that such numbers show that the agrarian society is ready to transition to industrial regime (Haberl, 2001 b).

Furthermore, the industrial society relies more on the imported energy than the system can produce such as the DE of Austria in 1995 was 92 GJ/cap whereas the DEC was 196 GJ/cap, the difference being covered by the imported energy i.e. 127 GJ/cap (Haberl, 2001 b). Finally, it can be concluded that the transformation in the societal energy metabolism accounts for higher input of energy and can pose significant sustainability problems such resource constraint and greenhouse gas emissions.

Other EFA studies on regional and national scales provides usefulness of using energy acocunts as per above mentioned methodlogy. Comparison between EU 15 and United States over a time series establishes the transition from bio-based energy to non-renewable energy for indutrialised nations (Haberl et al., 2006). Krausmann et al (2013) provided insights into energetic flows of the city of Vienna over long term temporal scale i.e. 1800 to 2006, Gingrich et al (2013) shows the transformation in the agricultural system from analyzing the energy flows of the Eisenwurzen Region. Singh & Haas (2016) showed the effects of energy flows on the island sustainability of Nicobar islands. All these studies point out that the inclusion of food and feed in the societal energetic metabolism provides further insights towards using energy in sustainable manner such as taking into account the biomass production for renewable energy use or conversion of society’s consumption pattern to become an industrialized economy.

# Chapter 3 Methodology

## 3.1 Introduction

This chapter contains the methodology followed in the research for the biomass and energy metabolism of Canada. It includes the data compilation of material flows, use of MFA indicators and the interpretation of those indicators in the analysis. For this research, the methods are consistent with Eurostat (2013) guideline followed by procedures in Krausmann et al (2015) and Haberl (2001a) for both biomass and energy flows. The primary data sources used to compile input data for biomass has been FAOSTAT (FAO, 2017) and for technical energy has been IEA (IEA, 2017 ). MFA (Krausmann et al., 2015) and EFA (Haberl , 2001a) methodologies have been used by the researches as discussed in the literature review to quantify and analyze biomass flows and energy flows both on global and national scale. Similar approach was taken to compile data for biomass and energy flows for Canada for the time series of 1990-2011.

## 3.2 System Boundary

To analyze material flows of a socio-economic system, a system boundary must be defined (Fischer-Kowalski et al., 2011; Krausmann et al., 2015). In MFA, the system boundary is the national economy being considered and the flows which enter the economy either from other political boundaries i.e. imports or the natural environment are referred to as input flows, whereas the output flows are the discharges to environment and exports to other economies. Furthermore, MFA accounts for relevant flows to be consistent with national accounts (Krausmann et al., 2015) and follows the following two principles:

i) Flows that occur between the national economy and natural environment, i.e. primary extraction of materials from the environment for example extraction of crude oil, and the discharge of processes to the natural environment i.e. emissions and wastes

ii) Flows occurring between the political boundary of the national economy and the rest of world (ROW) economy. These are the import and export flows.

Flows that enter or leave the national economy are of value in MFA and flows within the economy are not considered. The system boundary defined for this research is the national economy of Canada and flows categorized in two different ways:

a) Input flows of biomass and technical energy i.e. domestic extraction (primary production) of biomass and technical energy in Canada plus the imports of the same from ROW to Canada.

b) Output flows are the exports of bio-based materials and technical energy from the national economy of Canada to ROW economy and environment.

## 3.3 Methodology for MFA

MFA indicators and data compilation to analyze biomass flows used in this study are derived from the EUROSTAT methodology (Eurostat, 2013) and the definitions of these indicators taken from Krausmann et al (2015). For EFA, methodology and indicators provided in (Haberl , 2001a) are used to replace those of in MFA. Both set of indicators are consistent to previous MFA and EFA studies discussed in the literature review.

### 3.3.1 Indicators for biomass flows

1) *Domestic Extraction (DE):* Domestic extraction is the primary yearly production of biomass at harvest for useful economic activity that contains a certain value in the given socio-economic system. Key components of the domestic extraction of biomass for Canada are primary crops (cereals, roots & tubers, sugar crops, oil crops, vegetables, fruits, fibers and other crops), fodder crops and grazed biomass, crop residues, wood and timber, and fisheries including aquatic plants.
2) *Imports:* Imports account for all physical biomass products from primary harvest to processed products being accounted for in terms of weight (tons) traded in from other political economies at the physical border of Canada. The imports in this research are quantified yearly
3) *Exports:* Exports account for all physical biomass products from primary harvest to processed products being accounted for in terms of weight (tons) traded out to other political economies at the physical border of Canada. The exports in this research are quantified yearly
4) *Direct Material Input:* Direct Material Input accounts for the biomass material which enters the economy for economic purposes. These materials are produced and consumed within the economy and therefore comprises both Domestic Extraction and Imports in the MFA flows. In this research DMI for biomass is calculated in terms of weight (tons) for DE and Imports of Canada on a yearly basis.

   DMI = DE + Imports

5) *Domestic Material Consumption:* Domestic Material Consumption (DMC) comprises biomass materials consumed within the economy for economic purposes. It is calculated by adding the Domestic Extraction plus the physical imports minus the physical exports. In this research DMC is expressed in terms of weight (tons) on a yearly basis for Canada.

   DMC = DMI – Exports (DE + Imports – Exports)

6) *DE to DMC ratio:* The ratio of domestic extraction to domestic material consumption indicates the dependence of the physical economy on domestic raw material supply. This study therefore denotes the DE to DMC ratio as domestic resource dependency (Wiesz et al., 2006).

7) *Physical Trade Balance:* Physical Trade Balance (PTB) equals physical imports of biomass minus physical exports of biomass. A positive trade balance indicates that the economy is a net importer of goods whereas a negative trade balance shows the economy is based on exports. In this research, it is calculated in terms of weight (tons) for Canada on yearly basis

   PTB = Imports – Exports

DE, Imports, Exports and DMC have been also expressed in terms of per capita for further comparison with US and EU-15. The population figures have been taken from (FAO, 2017) on a yearly basis.

### 3.3.2 Data Compilation and Sources for biomass flows

Data compilation for biomass flows has been done for three categories i.e. i) primary production ii) imports and iii) exports. The major data source has been FAO (2017) and data not covered by FAO(2017) such as grazed biomass, crop residues and livestock weight has been calculated in accordance with MFA methodology (Eurostat, 2013; Krausmann et al., 2015). All the data has been reported in tons and converted in tons using appropriate factors e.g. conversion of timber production from cubic meter to tons. In the proceeding sections data compilation for each of the three categories and their sub-categories is explained in detail

### 3.3.2.1 Domestic Extraction

The data referred to here as primary production is same as domestic extraction used in MFA indicators. Primary production has been divided into five sub-categories, these categories are a) primary crops, b) crop residues, c) fodder crops and grazed biomass, d) wood and lastly e) Fish capture and other aquatic animals and plants.

**Primary crops**

Primary crops for Canada includes 62 different crops and have been classified into the following crop categories as per Krausmann et al (2015)

1) Cereals
2) Roots & Tubers
3) Sugar Crops
4) Pulses
5) Oil bearing Crops
6) Vegetables
7) Fruits
8) Fibre Crops
9) Other Crops

Primary crops data has been compiled from the FAO (2017) database and includes the above given crops. All the crops data has been reported "as is weight" at the time of crop harvest as per the MFA convention (Krausmann et al., 2015). Tree nuts have been excluded from the list since Canada has no production for these type of crops (FAO, 2017). Other crops in for primary crops includes tobacco harvest.

**Crop Residues**

The data presented for production of crops from FAOSTAT (FAO, 2017) provides only the primary harvest of the crop but does not provide quantitative number of crop residues from the fresh harvest. These crop residues can be of further economic, nutritional and energy value. As per the EUROSTAT (Eurostat, 2013) methodology, crop residues must be accounted for separately. Krausmann et al (2015) provides the necessary calculation methodology for assuming useable crop residues. This calculation is done in three steps which are i) identification of crops subject to produce usable residues ii) assuming available crop residues by using harvest factor and iii) harvest of crop residues using recovery rate. This estimation is used to keep the calculation of crop residues consistent with other MFA studies as harvest factor and recovery rates vary from area. In this study for Canada the crop residues are theoretically calculated for three types of crops i.e. cereals, sugar crops and oil crops as per (Krausmann et al., 2015). Estimation of available crops residues from the above-mentioned crop categories was done using the harvest factors provided (Table 2)

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

**Table 2 Harvest factor of Crops for North America (Krausmann et al., 2015)**

| Crop | Harvest Factor |
|---|---|
| Wheat, other cereals | 1.2 |
| Rice, Paddy | 1.2 |
| Maize | 1.2 |
| Millet | 1.2 |
| Sorghum | 1.2 |
| Sugar Cane | 0.7 |
| Cassava | 0.8 |
| Soybeans | 1.2 |
| Oil Palm Fruit | 1.9 |
| Castor Beans | 0.4 |
| Rapeseed, oil crops | 2.3 |

After calculating the estimated number of available crop residues, the possible recovoreable amount was calculated as only a fraction of the amount can be harvested (Krausmann et al., 2015). The equation 2 below provides the the method to calcuate used crop residues based on the recovery rates used in this study for North America (Table 3).

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

### Table 3 Recovery rates for Crop Residues for North America (Krausmann et al., 2015)

| Crop | Recovery Rate |
|---|---|
| Cereals | 0.7 |
| Sugar Cane | 0.9 |
| Other oil crops | 0.7 |
| Oil Palm Fruit | 0.9 |
| Sunflower Seed | 0.5 |
| Rape seed | 0.7 |

**Fodder and Grazed Biomass**

The fodder and grazed biomass were compiled and estimated respectively using the methodology provided by (Krausmann et al., 2015). The fodder crops data was collected using the FAOSTAT production database for Canada (FAO, 2017). As per the data available there were two types of fodder crops which were included in the Domestic Extraction (DE) of this study i.e. forage and silage (maize) and mixed grasses and legumes. The data for the two was collected for the years 1990-2011 and was also used in the estimation of grazed biomass. According to MFA conventions these fodder crops need to be reported at air dry weight which is 15% moisture for consistent reporting of data. Moisture content for both these fodder crops is provided (Table 5)

**Table 4 Moisture content of fodder crops for North America (Gierlinger & Krausmann, 2012)**

| North America | |
|---|---|
| **Crop** | **Moisture content** |
| Forage and silage, maize | 85% |
| Mixed Grasses and Legumes | 80% |

The reported data on the fodder crops was then converted into air dry weight of 15% moisture content using the following equation 3 & 4 respectively

(3) $Factor_{mc} = (1\text{-}mc_{fresh}) / (1\text{-}mc_{airdry})$

(4) Air dry weight (at 15% mc) = fresh weight * $Factor_{mc}$

Using the air dry weight data of fodder crops, grazed biomass demand was estimated. As per the MFA guidelines (Eurostat, 2013), the grazed biomass by livestock needs to be accounted for biomass flows. Since the grazing data is not reported nationally or on FAOSAT (FAO, 2017), it is calculated using literature review. To be consistent with other MFA studies discussed in the literature review, this study used the grazing demand based estimation method illustrated in Krausmann et al (2015). The method described in Krausmann et al (2015) requires calculating roughage requirement of livestock based on the annual feed intake and number of livestock present in the socio-economic system. The number of livestock for Canada was obtained from FAOSTAT (FAO, 2017) and the annual feed intake of the following livestock (Table 5)

**Table 5 Values represent annual intake of air dry biomass (15% mc) in t / head and year for North America (Gierlinger, 2012)**

| | Annual Intake of forage[t/head and year] |
|---|---|
| Cattle | 5 |
| Sheep & Goats | 0.5 |
| Horses | 3.7 |
| Mules | 2.2 |

(5) Roughage requirement = livestock [number] * annual feed intake [t per head and year]

Since roughage estimated may consist of fodder biomass or grazed biomass, the estimated amount of grazed biomass is calculated by subtracting the quantity of available fodder crops as per equation 6

(6) Demand for grazed biomass = roughage requirement [t at 15% mc] – fodder crops [t at 15% mc].

**Wood**

Wood Biomass extraction consists of two types of wood, timber and wood fuel. The production data for both types of wood was taken from FAOSTAT (FAO, 2017) in the form of yearly compilation for Canada from 1990 to 2011. The wood data represents wood extraction from forest, short rotation plantation and wood from agricultural lands. FAOSTAT represents the data in density and differentiates between coniferous and non-coniferous, hence as per the MFA convention appropriate factors (Table 6). Furthermore, FAOSTAT reports wood under bark i.e.

without including the bark, a factor of 1.1 was applied to the coefficient to include wood removals at 15% air dry weight for consistency

**Table 6 Conversion coefficients used to convert quantities given in volume (scm) into weight (at 15% mc) for coniferous and non-coniferous wood (Krausmann et al., 2015)**

| | **Density incl. bark (t at 15%mc/scm** |
|---|---|
| Coniferous | 0.572 |
| Non-coniferous | 0.748 |

**Fish Capture and Other aquatic plants & animals**

This biomass flow category acocunts for fisheries and aquatic plants & animals captured from unmanaged seawater and freshwater resources of Canada. Cultivated fish-aquaculture and other cultivated aqua plants are not included in this as they are a secondary category and depend on the primary domestic extraction explained above. Recreactional fishing is also included in this flow. The data of fish capture and aquatic plants & animals has been compiled from FAO Fishery statistics (FISHSTAT, 2017) for Canada for the years 1990-2011.

### 3.3.2.2 Import and Export Trade Flows

Import and Export trade flows consist of movement of primary and secondary goods from and to other political economies from the system boundary defined (Singh et al., 2012). The traded goods can be in the form of raw material like unmilled cereals or semi-finished goods for example steel ingots as well as fully processed such as furniture (Krausmann et al., 2015). The import and export data of biomass for Canada for this study has been compiled from (FAO,

2017) and (FISHSTAT, 2017) which is consistent with MFA convention. Only the goods which add to or deplete the physical stock of biomass are considered as import and export of biomass in this study.

**Primary Crops**

Primary crops in the import and export flows of biomas consists of i) cereals primary and processed products without bear, ii) root and tubers primary and processed products, iii) sugar crops primary and processed products, iv) pulses primary and processed products v) nuts primary and processed products vi) oil bearing crops primary and processed products, vii) vegetables primary and processed products, viii) fruits primary and processed products without wine, ix) fibres primary and processed products and x) other crops primary and processed where other crops include tobacco and products, spices, alcoholic beverages, stimulant (tea and coffee) and textile (cotton lint, cotton linter, cotton waste,cotton carded and combed, cottonseed and silk raw)

**Crop Residues**

For the import and export biomass flows of Canada, only the data of straw is available in FAO(2017). Hence for the purpose of this study straw is the only crop residue included as import and export biomass flow of Canada for the years 1990-2011.

**Fodder Crops and Animal Feed**

Fodder crops and Animal feed data has been compiled from FAO(2017). The data inlcudes the import and exports values for alfalfa meal and pellets, crude materials, dregs from brewing distillation, feed and meal gluten, feed supplements, feed compound , feed vegetable products ,food wastes,forage products and pet food.

**Wood and wood products**

Wood and wood products include timber primary and processed and wood fuel primary and processed. Timber primary and processed wood products include the following products (FAO, 2017):

1) Industrial roundwood, coniferous (export/import)
2) Industrial roundwood non-coniferous tropical (export/import)
3) Industrial roundwood, coniferous (export/import)
4) Industrial roundwood, non-coniferous non-tropical (export/import)
5) Sawnwood, coniferous
6) Sawnwood, non-coniferous all
7) Veneer sheets
8) Plywood
9) Particle board and OSB
10) Hardboard
11) MDF/HDF
12) Other fibreboard
13) Mechanical wood pulp

14) Semi-chemical wood pulp

15) Chemical wood pulp

16) Chemical wood pulp, sulphate, unbleached

17) Chemical wood pulp, sulphate, bleached

18) Chemical wood pulp, sulphite, unbleached

19) Chemical wood pulp, sulphite, bleached

20) Dissolving wood pulp

21) Pulp from fibres other than wood

22) Recovered paper

23) Newsprint

24) Printing and writing papers

25) Printing and writing papers, uncoated, mechanical

26) Printing and writing papers, uncoated, wood free

27) Printing and writing papers, coated

28) Other paper and paperboard

29) Household and sanitary papers

30) Wrapping and packaging paper and paperboard

31) Case materials

32) Cartonboard

33) Wrapping papers

34) Other papers mainly for packaging

35) Other paper and paperboard n.e.s. (not elsewhere specified)

Whereas the Wood fuel includes the following product cateogries in forestry trade flows:

1) Wood fuel, all species (export/import)
2) Wood charcoal
3) And Wood residues

Some of the above mentioned products are reported in cubic meters by FAO(2017) and for the aim of consistency this study converts those product values to tonnes using UNECE(2017) forest product conversion factors (Table 7).

## Table 7 Forest Product Conversion factors (UNECE, 2017)

| Product | Cubic meter to Metric Tonne |
|---|---|
| ROUNDWOOD | |
| WOOD FUEL, INCLUDING WOOD FOR CHARCOAL | 1.38 |
| Coniferous | 1.60 |
| Non-Coniferous | 1.33 |
| INDUSTRIAL ROUNDWOOD (WOOD IN THE ROUGH)Coniferousm Non-Coniferous, of which:Tropical | 1.37 |
| SAWLOGS AND VENEER LOGS Coniferous | 1.43 |
| SAWLOGS AND VENEER LOGSNon-Coniferous | 1.25 |
| PULPWOOD (ROUND & SPLIT) | 1.48 |
| PULPWOOD (ROUND & SPLIT) Coniferous | 1.54 |
| PULPWOOD (ROUND & SPLIT) Non-Coniferous | 1.33 |
| OTHER INDUSTRIAL ROUNDWOOD | 1.33 |
| OTHER INDUSTRIAL ROUNDWOOD Coniferous | 1.43 |
| OTHER INDUSTRIAL ROUNDWOOD Non-Coniferous | 1.25 |
| WOOD CHIPS AND PARTICLES | 1.60 |
| WOOD RESIDUES | 1.50 |
| SAWNWOOD Coniferous | 1.82 |
| SAWNWOOD Non-Coniferous | 1.43 |
| VENEER SHEETS | 1.33 |
| PLYWOOD | 1.54 |
| PARTICLE BOARD (including OSB) | 1.54 |
| HARDBOARD | 1.05 |
| MDF (Medium Density) | 2.00 |
| INSULATING BOARD | 4.00 |

**Fish capture and aquatic plants & animals**

Fishery trade data has been compiled from (FISHSTAT, 2017) for Canada for the years 1990-2011.

**Animal Products**

This biomass trade flow category includes live animals (livestock), meat and meat products (primary and processed), milk and mlik products (primary and processed), eggs, animal fat & animal fat products (primary and processed) and products from animal skin and hair. Data for all the above mentioned flows was compiled from FAO(2017). FAOSTAT however reports live animals in terms of numbers and for the consistency of the study, the number needed to be converted into weight in tonnes (Table 8).

**Table 8 Average Body weight for Livestock in Canada (Warrington, 2001)**

| Animal | Avg Body weights in Kg |
|---|---|
| Asses | 550 |
| Cattle | 483 |
| Chickens | 2.3 |
| Ducks | 2.8 |
| Goats | 60 |
| Horses | 550 |
| Pigs | 140 |
| Rabbits and hares | 3 |
| Sheep | 54.5 |
| Turkeys | 5 |

## 3.3.2 Indicator for energy flows

Energy flow analysis in this study has been conducted using methodology presented by (Haberl H. , 2001a) in line with MFA methodology and studies as discussed in the literature review. Basic data compilation for EFA is the same as of MFA with some changes in the nomenclature of the indicators as well as distinction between biomass used for energy and non-energy purposes. Source of data compilation and energy conversion factors was IEA database for Canada for the years 1990-2011 (IEA, 2017 )

#### 3.3.3.1 Domestic Extraction (DE)

Domestic Extraction to explain the energetic metabolism of the society depends on the following types of energy flows:

a. Biomass flows including timber & crop residues (referred to as Food and Feed in EFA of this study)
b. Coal
c. Crude Oil
d. Natural Gas
e. Nuclear
f. Hydro
g. Geothermal, Solar and Wind Power
h. Biofuels and Waste

Food & Feed data compiled in the MFA part of biomass in this study was used to represent energy flows. The data represented in mass was converted to energy using the moisture content equations (4) and (5) in MFA for 15% air dry moisture content and then appropriate dry matter energy factors were applied to each biomass category to convert into gross calorific value. Table 10 below shows the moisture content and energy content of Food & Feed materials used in EFA. Biomass for technical energy was also subtracted from the total energy flows of biomass compiled in the MFA part of this study to provide consistent data for Food & Feed only in the EFA.

### Table 9 Average Moisture Content and Air Dry @ 15% Energy Content of Food & feed Materials (Gierlinger & Krausmann, 2012)

| | Average Moisture Content | GCV Factor (GJ/Ton) |
|---|---|---|
| Cereal | 14% | 18.3 |
| Root & Tubers | 74% | 16.3 |
| Sugar Crops | 82% | 16 |
| Pulses | 11% | 20 |
| Treenuts | 5% | 25 |
| Oil Bearing Crops | 28% | 25 |
| Vegetables | 92% | 18.5 |
| Fruits | 81% | 20 |
| Fibre Crops | 10% | 19.5 |
| Other Crops | 24% | 19 |
| Spices | 58% | 19 |
| Straw | 14% | 18 |
| Other Crop residues | 81% | 17.5 |
| Fodder Crops | 81% | 18.5 |
| Meat | 50% | 22 |
| Animal Fat | 50% | 40 |
| Eggs | 100% | 30 |
| Milk | 100% | 25 |
| Timber Industrial Roundwood | 20% | 20 |
| Fuel Wood and Other Extraction | 20% | 20 |
| Alcoholic Beverages | 100% | 29 |
| Stimulant | 100% | 4.4 |
| Fish-Seafood | 59% | 22 |
| Aquatic Products-Other | 59% | 22 |

Data for coal, crude oil, nuclear, hydro, geothermal, solar and wind power was compiled in units of ktoe (equivalent of 1000 tons of oil) and converted to gross calorific value of the fuel in the units of joules. A calorific value is the amount of energy possessed by the material upon combustion. The difference between the “net” and the “gross” calorific value for each fuel is the latent heat of vaporization of the water produced during combustion of the fuel. As per the EFA convention the energy of material is represented in GCV to maintain consistency between Food & Feed and rest of the energy carriers referred to in this study as Technical Energy. Coal and crude oil are represented in NCV in IEA database (IEA, 2017 ) whereas electricity and nuclear energy has no latent heat of vaporization and is always considered in GCV. Biofuels & waste and natural gas is reported in GCV in the units of Tera Joules (TJ) by IEA (2017 ) and was compiled as is.

Table 10 and 11 show the conversion factors from ktoe to net calorific value and from net calorific value to gross calorific value respectively.

### Table 10 Conversion of Ktoe to Energy Content in GJ (IEA, 2017)

| Energy Carrier | Ktoe to GJ |
|---|---|
| Coal | 41.868 |
| Crude oil | 41.868 |
| Oil products | 41.868 |
| Natural gas | 41.868 |
| Nuclear | 13.818 |
| Hydro | 41.868 |
| Geothermal, solar, etc. | 41.868 |
| Biofuels and waste | 41.868 |
| Electricity | 41.868 |
| Heat | 41.868 |

### Table 11 Conversion of NCV to GCV (IEA, 2017)

| Energy Carrier | NCV to GCV |
|---|---|
| Coal | NCV = 95% of GCV |
| Oil | NCV = 95% of GCV |

#### 3.3.3.2 Imports and Exports

Imports and Exports are the physical quantity of energy carriers entering and leaving the Canadian physical border from other economies. Data source for Food & Feed was FAO (2017) and FISHSTAT (2017) and for Technical Energy was IEA(2017 ). All values for feed & feed were taken from MFA part of this study excluding the biomass for energy use and converted to GCV. For Technical Energy, the data was compiled in ktoe and converted to GCV using approaprite factors as discussed above. Biofuels & Waste and natural gas were compiled in GCV in the units of Tera Joule (TJ) as reported by IEA (2017 ). Import and Exports in this study inlude food & feed excluding biomass for technical energy use,  coal, crude oil, oil products, natural gas, electricity, heat, nuclear and biofuels & waste

#### 3.3.3.3 Direct Energy Input (DEI)

Direct Energy Input is the same indicaotr as DMI in MFA studies. In this case it is expressed in the unit of Joules. It can be caluclated as below

DEI = DE + Imports

#### 3.3.3.4 Domestic Energy Consumption

Domestic Energy Consumption (DEC) is similar to Domestic Material Consumption (DMC) in the MFA part of this study and is expressed in the unit of Joules. DEC can be caluclated as below:

DEC: DEI – Exports or DE+ Import – Exports

#### 3.3.3.5 DE to DEC ratio

The ratio of domestic extraction to domestic energy consumption indicates the dependence of the physical economy on domestic energy supply. Therefore, expressing the DE to DEC ratio as domestic resource dependency (Wiesz et al., 2006).

#### 3.3.3.5 Physical Trade Balance

Physical Trade balance is the difference between import and eport of energy carriers and is epxressed in a similar way as PTB in the MFA part of this study and is expressed in the unit of Joules

#### 3.3.3.6 Renewable Energy

Energy that is derived from natural processes (e.g. sunlight and wind) that are replenished at a higher rate than they are consumed. Solar, wind, geothermal, hydro, and biomass are common sources of renewable energy (IEA, 2017 )

# Chapter 4 Results

This chapter represents the main findings from the analysis run through time series of 1990-2011 for socio-economic metabolism of Canada. The results will be presented in two parts i.e. biomass flows and energy flows respectively. MEFA indicators discussed and explained in the methods chapter shall be used to interpret the socio-economic flows both for biomass and energy. Comparison with United States (Gierlinger & Krausmann, 2012) for relevant time series will also be discussed for each sub category.

## 4.1 Biomass Flows

### 4.1.1 Domestic Extraction

Average Domestic Extraction (DE) i.e. the amount of biomass extracted or produced in Canada from 1990 to 2011 was 376 Mt, and remained relatively constant (Figure 9), decreasing by only 3% over this period. DE reached a maximum of 411 Mt in 2004 and a minimum of 338 Mt in 2002. On average, Canadian DE was found 4.5 times lower than the USA (average of 1680 Mt/annum). Both countries showed relatively little change from 1990 to 2005 (Figure 9). However, on a per capita basis, Canada's DE is 2 times higher than USA, because the average population of Canada is small and is only 11% to US average population between 1990 and 2005 (Figure 10).

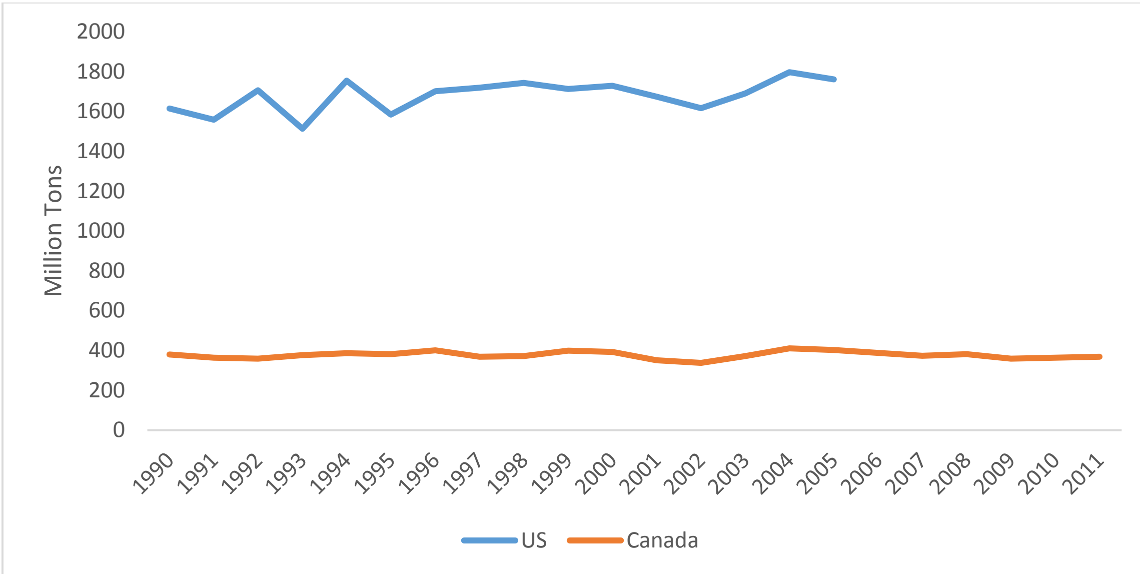


**Figure 9 Domestic extraction (DE) of biomass in Canada for the Time Series 1990-2011 and US values of DE from 1990 to 2005 for comparison.**

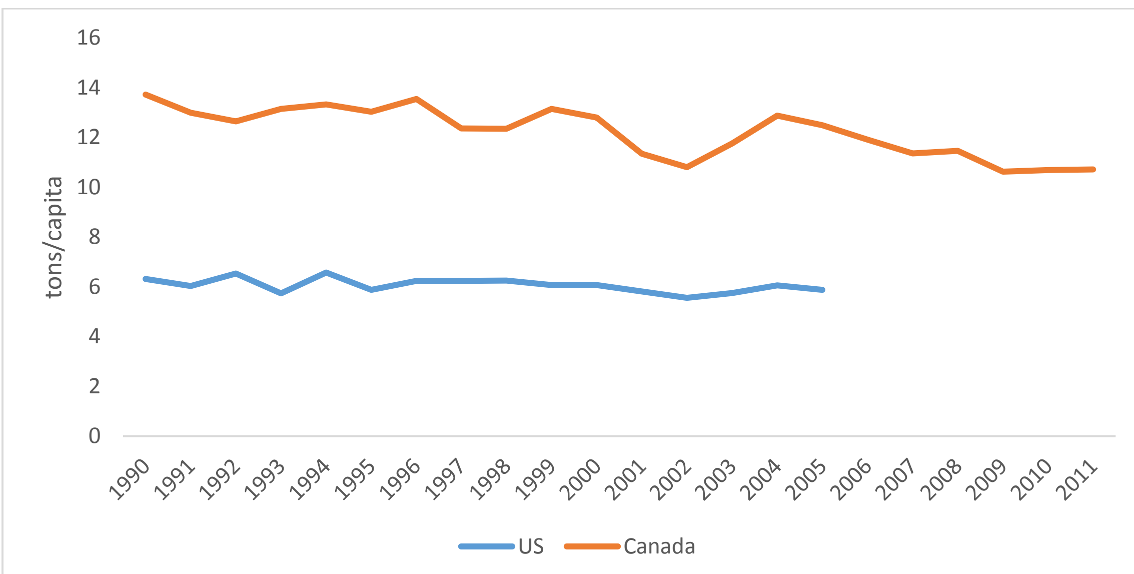


**Figure 10 Biomass DE/Capita for Canada from 1990-2011 and for US from 1990-2005**

The rise in 2004 was primarily because of increase in production of timber i.e. 124 Megaton, 23 Mt higher than the overall average of timber production calculated in this study, however the dip in 2002 is explained by reduced production of cereals which was 36 Mt against the average extraction of 50 Mt per year subsequently this resulted in less production of straw as well which was 30 Mt for a per annum average of 42 Mt. Also, the production of fodder crops i.e. mixed grass & legumes as well silage & forage declined to 79 Mt against average of 107 Mt per annum. Timber, fodder crops, cereal crops and straw share on yearly average of 27%, 28%, 13% and 11% of the total biomass extracted (Figure 11). These account for approximately 80% of biomass extracted from Canada and any increase as well as any reduction in the production of these crops pay a major contribution towards total biomass extraction of Canada.

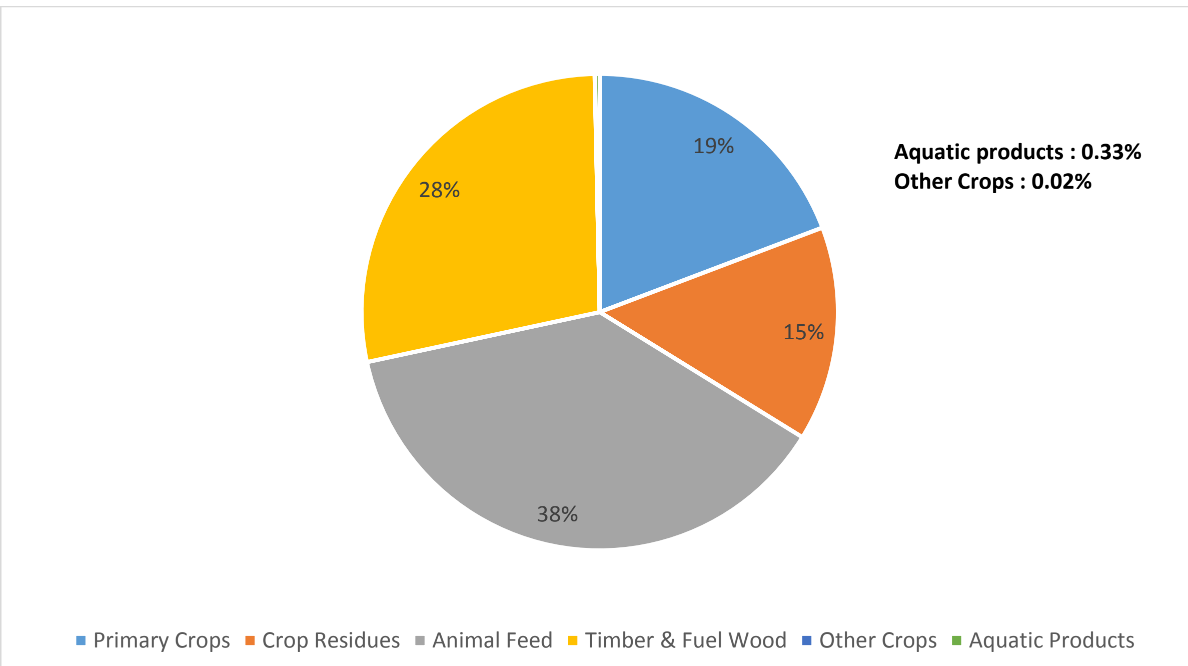


**Figure 11 Average share for DE Biomass Components for Canada over time series 1990-2011**

On average, animal feed was the biggest contributor to DE (38%), followed by timber (28%), primary crops (19%) and crop residues (15%) (Figure 11), with small contributions (0.33% and 0.02%) from aquatic products and other crops. Primary crops and the associated crop residues, increased over the time by 12 and 16%, respectively. However, all other biomass categories have decreased substantially (Appendix I and Figure 12). Animal feed and timber, which are the largest contributors to DE, have decreased by 13 and 7%, respectively. A detailed analysis of how these biomass categories have changed with time is provided in subsequent sections.

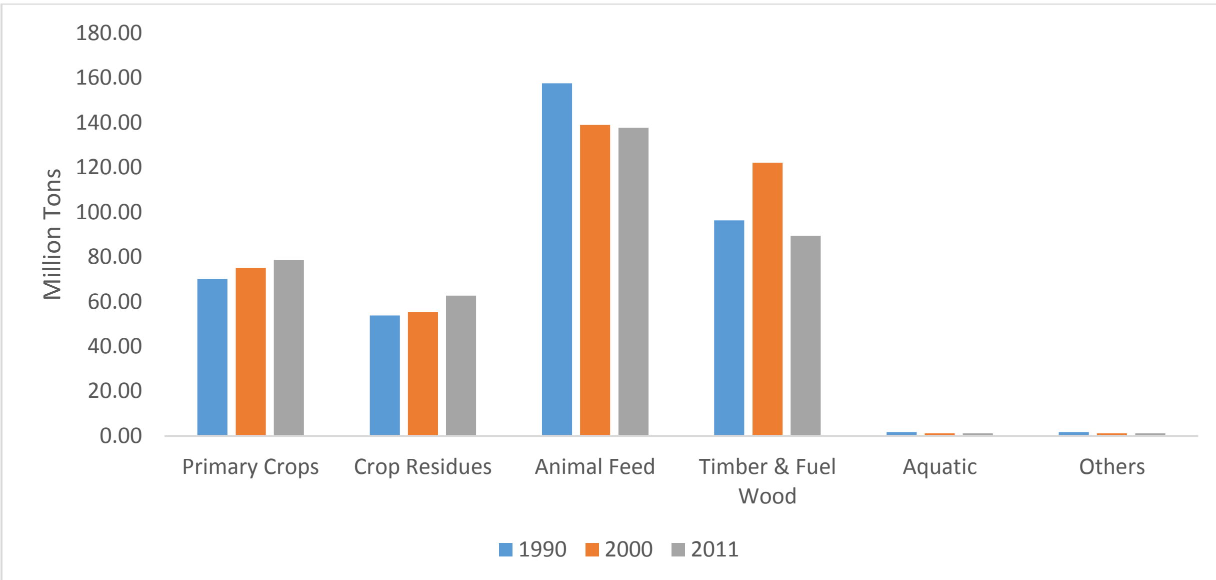


**Figure 12 DE Biomass Category wise for Canada years 1990, 2000 and 2011 respectively**

The increase in the production of primary crops can be explained by increase in exports of cereals from Canada (discussed in exports section) since the year 2000 (FAOSTAT, 2010), however the decrease in animal feed is explained by the fluctuations in the international market of forage and internal barriers (energy cost, transportation) as Canada is the third largest exporter of fodder crops in the world (Coulman, 2010) and increase in timber & firewood production from 1990 to 2000 and a subsequent decrease since 2000 owing to the 1996-2001 Canada-United States Softwood Lumber Agreement, the American anti-dumping and countervailing duties slapped on the industry from 2002 to 2006, a rise in energy and raw material prices, a decline in lumber prices and a higher exchange rate for the Canadian dollar (Statcan, 2010). Keeping in view the above analysis, it is important to analyze each biomass category in detail identifying the key contributors in each category hence providing a detailed breakdown of biomass extraction of Canada from the year 1990-2011.

**4.1.1.1 Primary Crops**

Primary crops consists of the production of cereals, roots & tubers, sugar crops, pulses, oil bearing crops, vegetables, fruits and fibre crops. Overall, production of primary crops has increased by 12% over the time period. Cereals has been the biggest contributor (69%) to this category, with an average annual production of 49.9 MT, but dropping from 56.8 MT in 1990 to 47.3 MT in 2011 due to a drop in exports (discussed in exports section) (FAOSTAT, 2010). Cereal production has fluctuated significantly, with a low of 36 MT in 2002. Wheat and barley have been the most produced cereal crops with an average production of 25 Mt and 11.5 Mt and constituting of approximately 50% and 23% of total cereal production during the study period (Figure 13).

In contrast, oil crops on average make up only 16% of this category; however, their production has increased by three times from 5.7 Mt in 1990 to 18.3 Mt in 2011 (Figure 13), such that as of 2008, they represent between 20 and 25% of the total primary crop production. This increase has been largely due to the increased production of rapeseed oil to meet the growing demand of canola oil and for use in biofuel industry (Statcan, 2011)[1]. Vegetables (average DE 2.3 Mt) and

[1] STATCAN does not provide the details of uses of canola oil, as well it does not provide the quantity of oil used separately as food and biofuel

fruits (average DE 0.7 Mt) form 3% and 1% of the DE (further discussed in imports and DMC section)

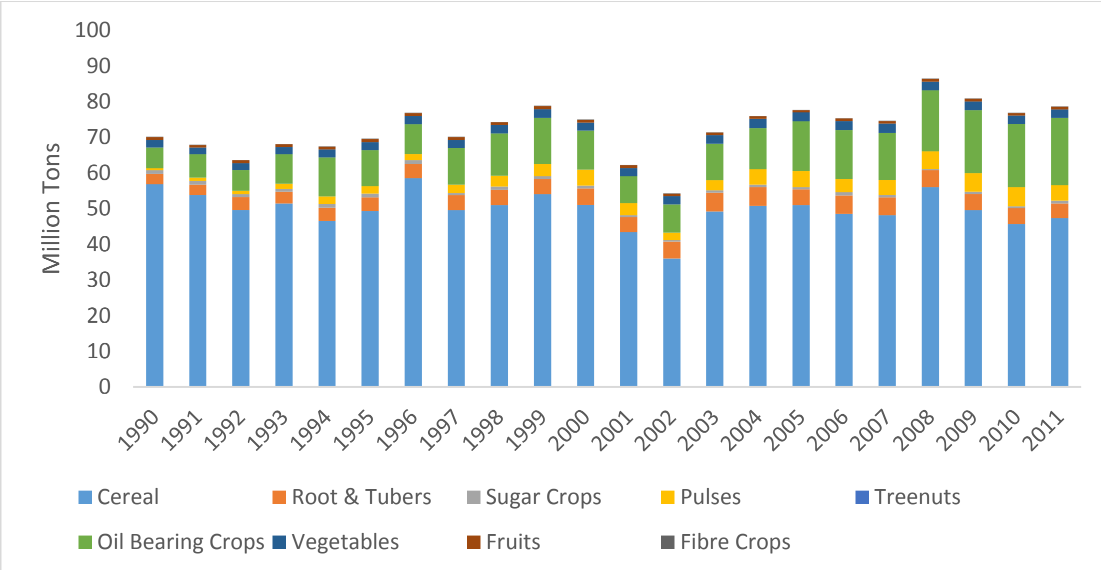


**Figure 13 DE Category Wise Primary Crops for Canada over time series 1990-2011**

Crop yields for Canada from 1990-2011 has improved for cereals, oil crops, vegetables and sugar crops (Figure 14), whereas remained constant for fruits and pulses. The area harvested for primary crops decreased from 26.2 million hectares to 25.3 million hectares. Cereals (66%) and oil crops (27%) form the major part of the average area harvested, with share of oil crops increasing from 15% in 1990 to 37% in 2011 (Figure 15 and Appendix I)

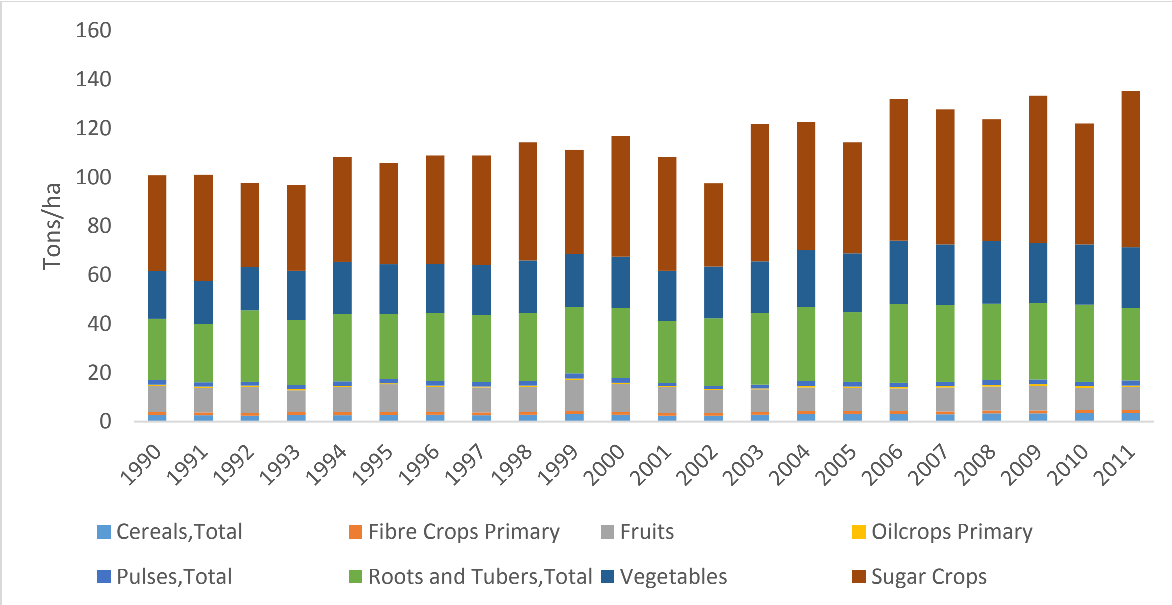


**Figure 14 Yield of primary crops for Canada from 1990-2011**

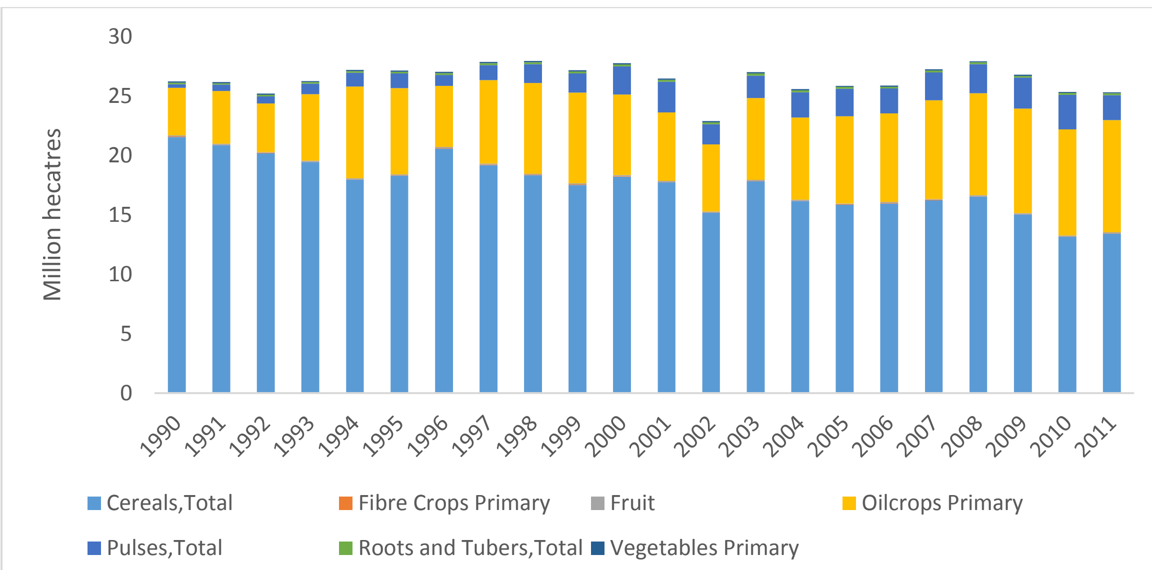


**Figure 15 Area harvested of primary crops for Canada from 1990-2011**

#### 4.1.1.2 Crop Residues

Crop residues consists of straw (residues from cereals) and residues from sugar & oil crops. It should be noted that the amount of crop residues that are available for harvest does not necessarily reflect the amount that is being used, as mentioned in the methodology. The amount of potentially harvestable straw has decreased from 47 Mt in 1990 to 39.7 Mt in 2011 (Figure 16). Since straw amounts were estimated based on cereal yields, they follow a similar pattern to the production of cereals (Figure 13). In contrast, other crop residues have increased from 6 Mt to 23 Mt in same time (Figure 16), reflecting the increased amounts of oil crops

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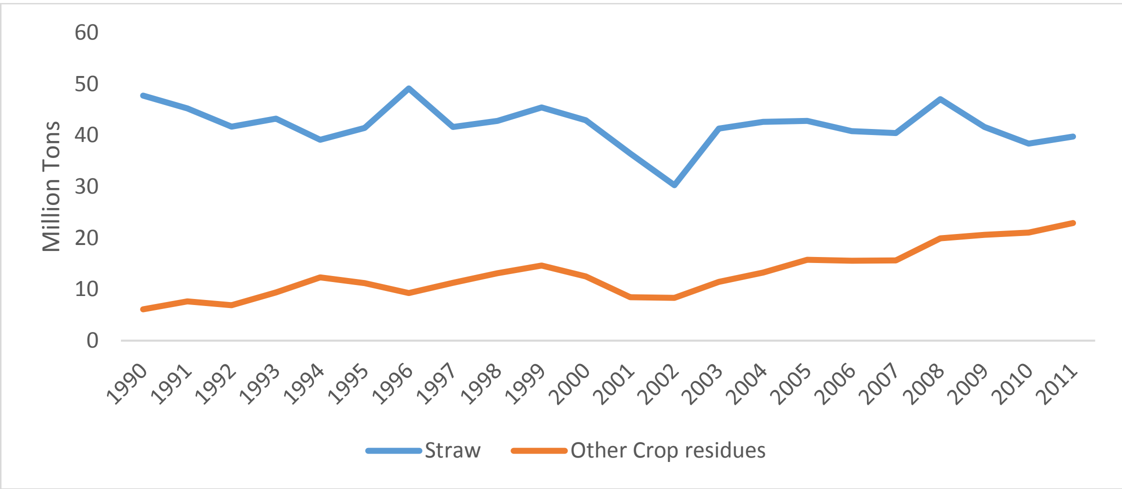



**Figure 16 DE Crop Residues for Canada over time series 1990-2011**

#### 4.1.1.3 Animal Feed

Animal feed production averaged 142.55 Mt over the period of 1990 to 2011, but there was an overall decline in production of 15% over the same period. On average, fodder crops comprise 75% of the total animal feed while grazed biomass is estimated at 25% (Figure 17)

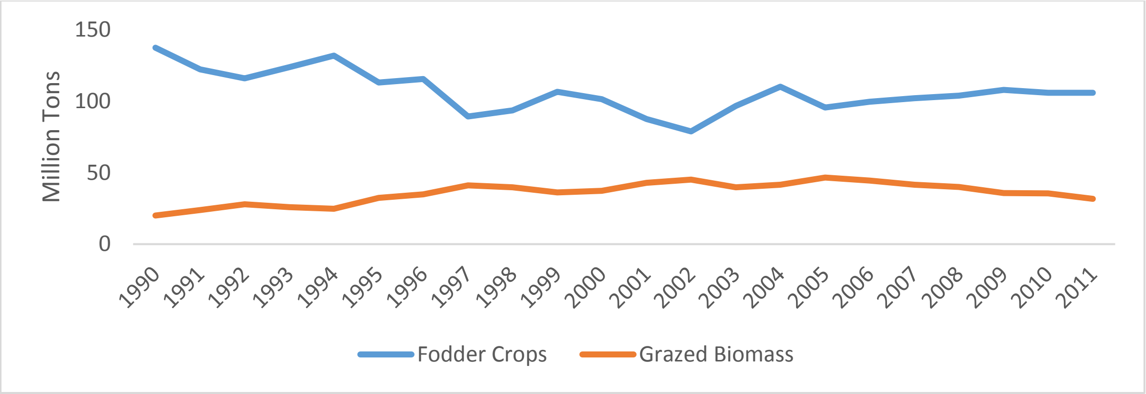



**Figure 17 DE Fodder Crops and Grazed Biomass for Canada over time series 1990-2011**

The decrease from 1994-2002 in the production of fodder crops has been majorly due to decline in exports (discussed in exports section). As mentioned in the methodology section the grazed biomass is the difference between total feed requirement and fodder production. Hence when fodder production increases the grazed biomass decreases (Figure 17).

The production of animal products i.e. meat, eggs and milk increased by 20% from 1990-2011(Appendix I). The mass conversion from animal feed to animal product on average was 9% during the study period.

#### 4.1.1.4 Timber & Fuel Wood

Timber & fuel wood consists of all forestry products as well as fire wood that is used for energy. On average, there was 105.7 Mt of timber & fuel wood produced, accounting for 28% of the total biomass production (DE) in Canada since 1990 (Figure 18). Timber production reached a peak high of 123 Mt in 2004 before declining to 68 Mt in 2009, the largest decline in 70 years (Couture et al, 2012). This significant drop was related to reduced demand for Canadian lumber due to the collapse in the United States housing market in 2008, and reduced global demand for Canadian pulp and paper products (Environment and Climate Change Canada, 2013). However, the industry has seen some recovery in recent years as the global economy improves (Environment and Climate Change Canada, 2013). Fuel wood, on the other hand, keeps on decreasing with a low of 0.9 Mt in 2011 showing Canada's dependence in the usage of natural gas and electricity largely due to the increased availability of natural gas and lower natural gas prices as well as extensive use and better efficiencies of gas and electrical heating furnaces (Environment and Climate Change Canada, 2013).


**Figure 18 DE Timber Industrial Round Wood and Fuel Wood for Canada over time series 1990-2011**

#### 4.1.1.5 Other Crops & Aquatic Products

Other crops i.e. tobacco for Canada and aquatic products such as seafood and aquatic plants in total comprise only 0.5% with an annual average harvest of 0.05 Mt and 1.1 Mt respectively

(Figure 19). A decline in aquatic products production was seen from 1990 to 1995 and has been stable since then, whereas tobacco has seen no change in the domestic extraction from 1990-2011.

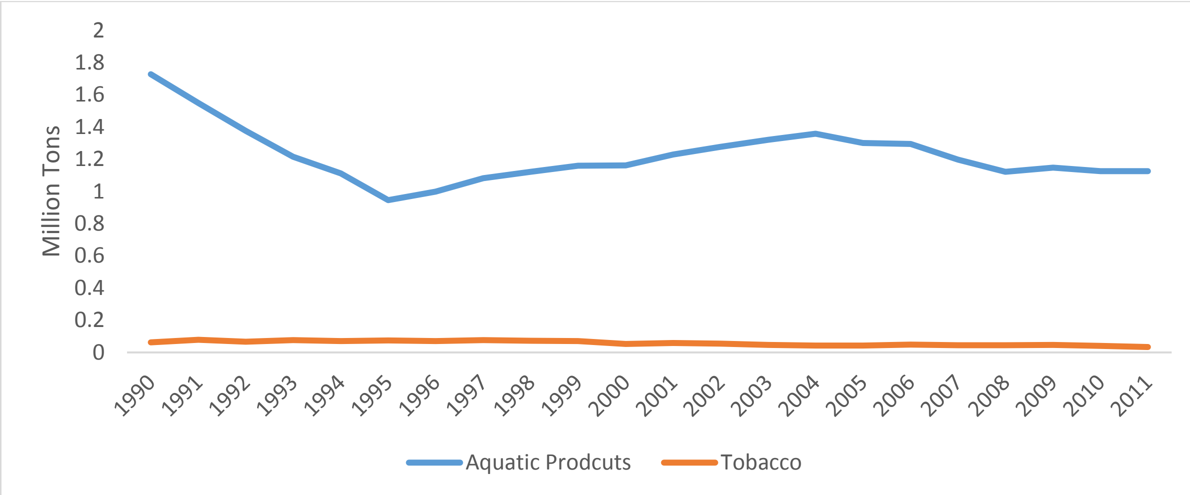



**Figure 19 DE Aquatic Products and Tobacco for Canada over time series 1990-2011**

## 4.1.2 Imports & Direct Material Input (DMI)

The imports account for all biomass processed and unprocessed coming into Canada from other countries. Overall, from 1990 to 2011, import increased by 150%, i.e. from 14.4 Million Tons in 1990 to 35.8 Million Tons in 2011, with a peak in 2008 of 40.3 Million Tons (Figure 20). Specifically, biomass imports increased steadily from 1990 to 2001, and then became relatively stable. The increase in biomass imports has been largely due to many factors such as Canada's limitation to grow variety of products due to climatic conditions, a multicultural society demanding a variety of products, and competition in the market demanding fresh and profitable products (Kissinger, 2013).

Comparing Canada and the USA, physical imports of biomass for US has seen an increase from 1990-2005 with an increase of 76% (Figure 20), whereas during the same time Canada has seen an increase of 170%. The absolute physical biomass trade for US is quite high as compared to Canada from 1990-2005 i.e. 84Mt average per annum compared to 28Mt for imports.

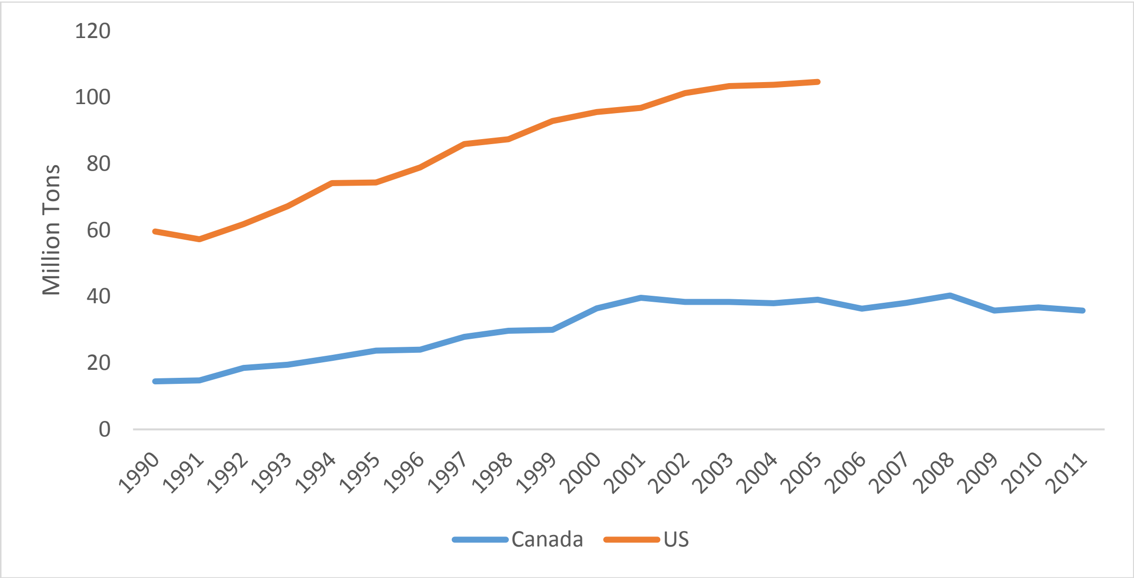



**Figure 20 Biomass physical imports for Canada over time series 1990-2011 and US for 1990-2005**

Imports per Capita of Canada from 1990-2005 have been 3 times than US i.e. 1.2 tons per capita as compared to 0.3 tons per capita (Figure 21). Per capita import for Canada has been increased by 132% since 1990 as compared to US where physical imports/capita has shown a slight increase of 50%.

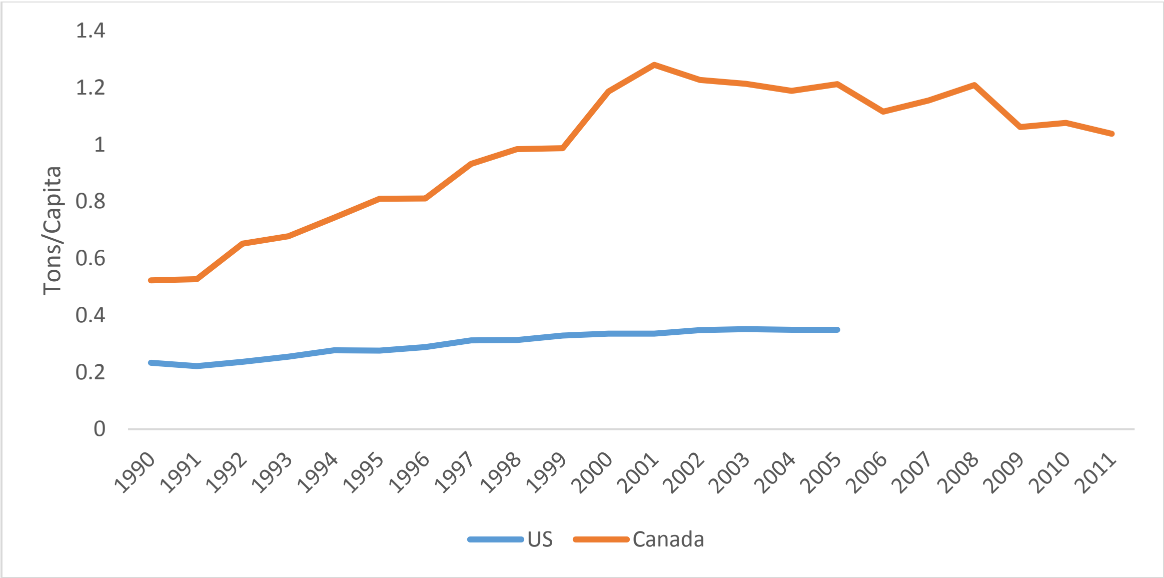



**Figure 21 Biomass import/capita for Canada from 1990-2011 and for US from 1990-2005**

Timber & fuel wood and primary crops represent the biggest share of imports, averaging 47% and 40% of the total imports, respectively (Figure 22). However, timber imports showed a decline from the year 2004 to a minimum in 2011 i.e. from 20 Mt to 15 Mt. In contrast, other categories increased. The largest imports in primary crops are fruits, cereals, vegetables and sugar crops which make up an annual average of 31%, 24%, 18% and 13%, respectively, of total primary crops imports (Appendix I and Figure 22). The remaining 13% of imports are composed of animal feed, animal & products (livestock, meat, milk, eggs and milk), aquatic products and other crops (tobacco and products, spices, alcoholic beverages, stimulant and textile).

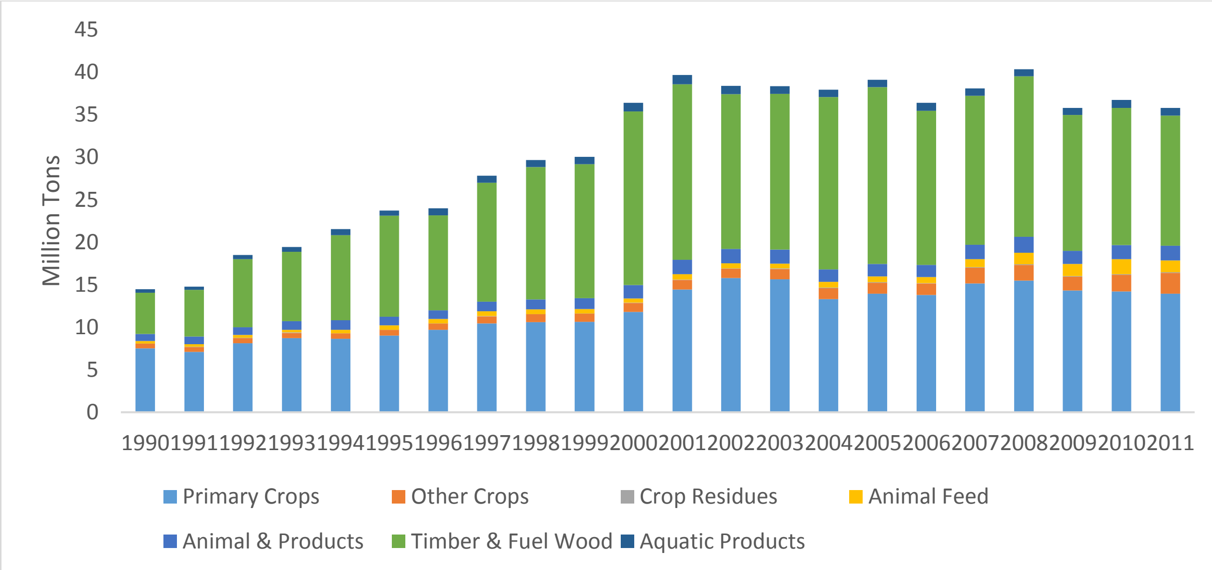



**Figure 22 Biomass category physical imports for Canada from 1990-2011.**

Direct Material Input (DMI) is the sum of domestic extraction and imports coming into the national economy, and it provides the physical flows that enter a system boundary. From 1990-2011, Canada's biomass DMI has been on an average per annum 407.8 Mt, and has increased from 394 Mt in 1990 to 405.3 Mt in 2011(Figure 23). The trend of DMI shows variation in the 22-year time series largely depending on the domestic extraction as both follow the same pattern. DMI comprises 92% DE on average per annum as compared to 8% of on average per annum of Imports, though in recent years share of imports has slightly increased with 10.2% in 2002. This largely shows the reliance of Canadian economy on domestic extraction of biomass, other than fruits and vegetables, rather than imports as imports are majorly due to economic and geographical conditions of Canada and have little or less impact to the Canadian economy (Kissinger, 2013)

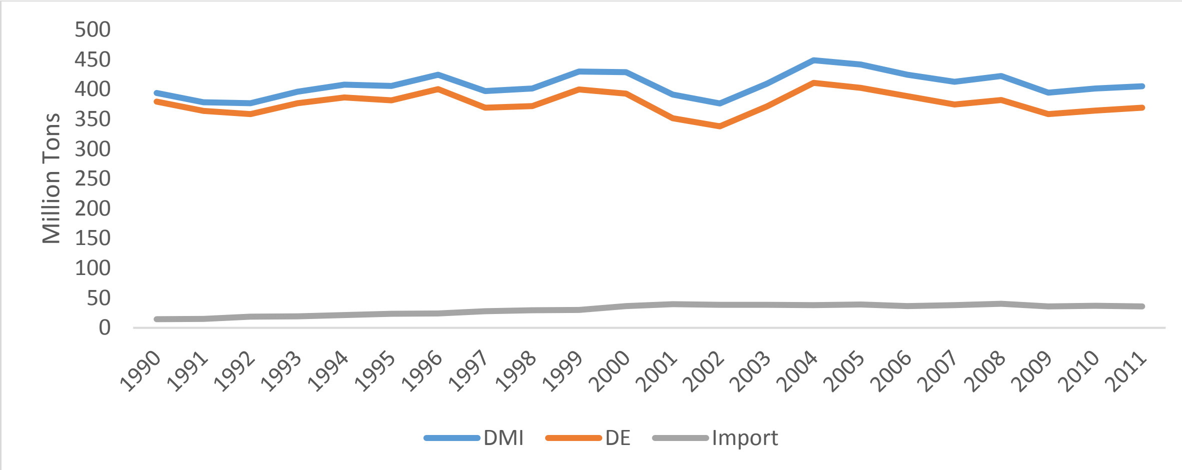



**Figure 23 Biomass DMI, DE and Physical Imports for Canada from 1990-2011.**

### 4.1.3 Exports

The exports account for all biomass processed and unprocessed leaving from Canada to other economical boundaries. Biomass exports for Canada grew by 60%, from 83 Mt in 1990 to a peak of 133 Mt in 2006, dropping to 113 Mt in 2011 (Figure 24). Though biomass imports for Canada increased by 150% but in terms of physical quantity the average per annum biomass physical exports are three times the average biomass physical imports. Exports of biomass for US has seen an increase from 1990-2005 of 11%, whereas during the same time Canada has seen an increase of 56%. Average exports for US is quite high as compared to Canada (110 Mt) from 1990-2005 i.e. 177 Mt. Interestingly the gap between the two countries for physical exports has been reducing since recent years showing Canadian economy's reliance on biomass exports (Figure 24).

Exports of biomass per capita of Canada from 1990-2005 have been 5 times higher on average per annum than US i.e. 3.63 tons per capita as compared 0.63 tons per capita for US (Figure 25).

Per capita export for US has dropped by 6% whereas physical exports/capita of Canada has increased by 34%.

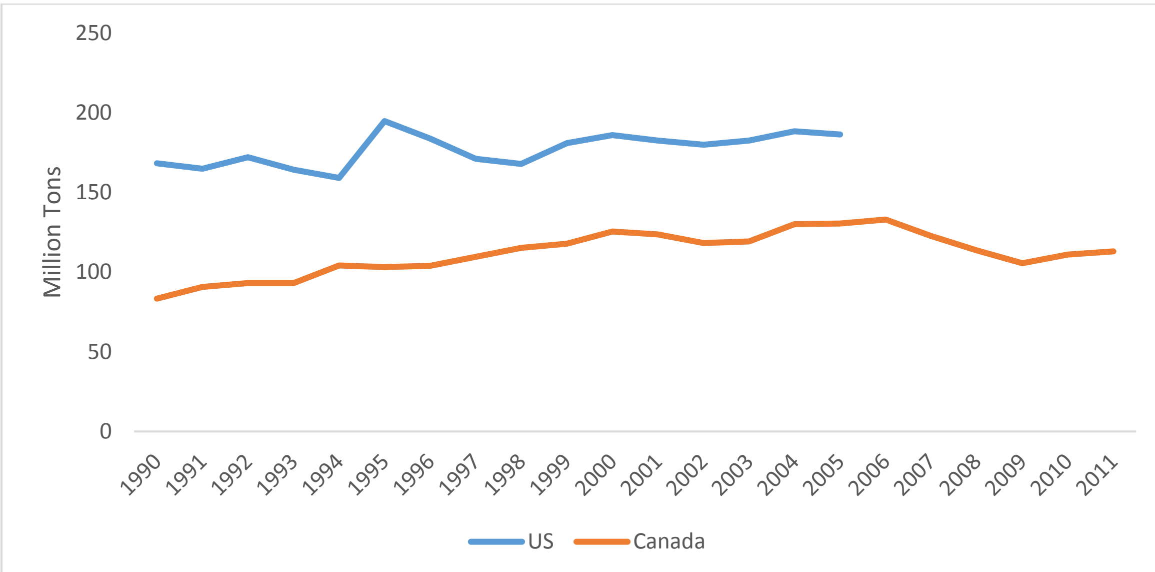



**Figure 24 Biomass physical exports for Canada from 1990-2011 and for US from 1990-2005**

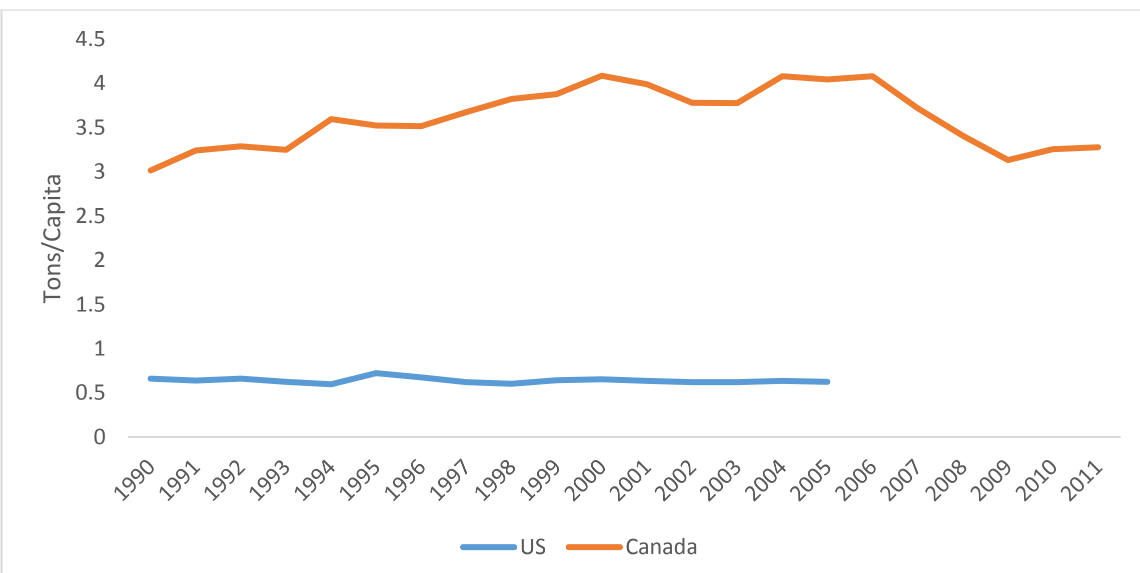



**Figure 25 Biomass physical exports/capita for Canada from 1990-2011 and for US from 1990-2005**

The major export for Canada during this time was timber & fuel wood, which on average comprised 62% of total biomass physical exports (Figure 26). 99% of forestry export was timber, with the remaining 1% belonging to other forestry extractions. From 1990 to 2005, the timber industry saw a growth of 80% in physical exports (i.e. from 50Mt to 89Mt) before falling off to 51Mt in 2010, the lowest since 1990 largely due to US-Canada lumber dispute (Couture & Macdonald, 2012).

Primary crops are the second biggest biomass physical export of Canada from 1990-2011, comprising 32% on average per annum of the total biomass physical exports. The major primary crops exports have been cereals and oil crops i.e. 67% and 19% of total primary crop exports i.e. 23.2 Mt and 7 Mt respectively (Figure 26). The top crop exports amongst cereals is wheat & products which comprises 75% of the cereal exports, reflecting on Canada's position as one of the world's largest wheat exporter (FAOSTAT, 2010) . For oil crops, rapeseed & products constitute of 89% of the average total per annum exports, which explains increasing oil crop production (discussed in DE section). The decline in production of forage products from 1994-2002 (discussed in DE section) is also explained by decrease in exports i.e. 38%.

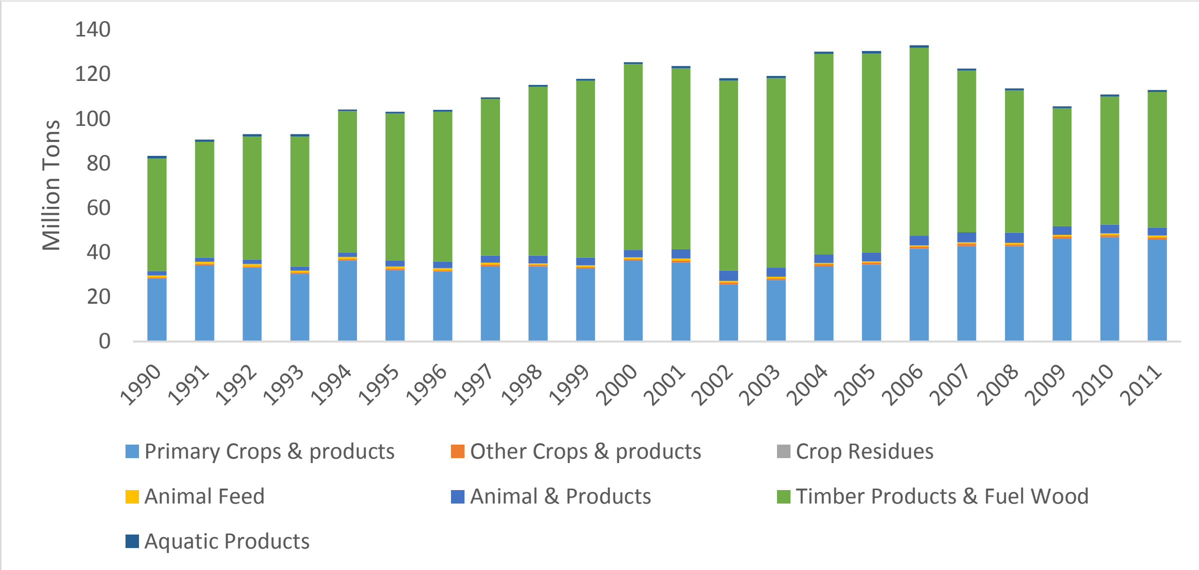



**Figure 26 Biomass Exports Categories for Canada from 1990-2011.**

### 4.1.4 Domestic Material Consumption

Domestic Material Consumption is the difference between Domestic Material Input and Exports. It represents the biomass used in the system to build and maintain stocks such as human population, livestock and artefacts. Average DMC for biomass for Canada from 1990-2011 has been 295 Mt i.e. 73% of Direct Material Input and 78% of Domestic Extraction (Figure 27). The similar pattern between DMC and DE clearly shows the dependence of Canadian biomass consumption on Domestic Extraction (92% of DMI). The dips in DMC are reflected in the dips of Domestic Extraction as well, for example in 2002, Domestic Material Consumption and Domestic Extraction were at their lowest point i.e. 258 Mt and 338 Mt respectively

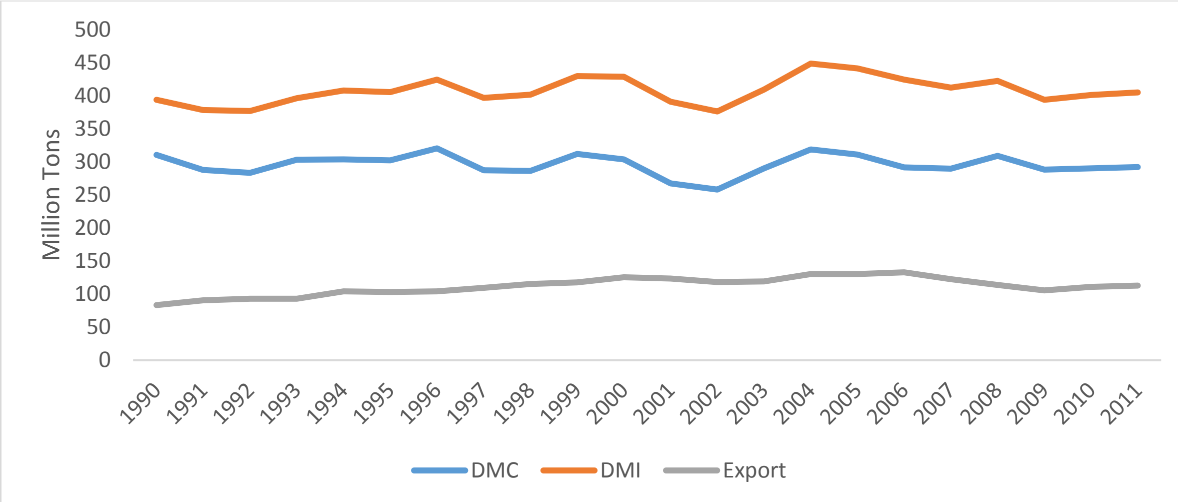



**Figure 27 Biomass DMI, DMC and Physical Exports for Canada from 1990-2011**

48% of the total biomass consumed in Canada from 1990-2011 is animal feed, and the major part of it is formed by fodder and grazed biomass for livestock feed. Livestock number has increased from 22.7 million head to 26.4 million head where major increase has been in pigs (23%), chicken (48%) and cattle (8%) (Figure 28). Fodder crops consumption decreased from 1994 to 2002, which was mainly due to unavailability of fodder crops as exports decreased, showing an increase in grazed biomass (as discussed in DE section).

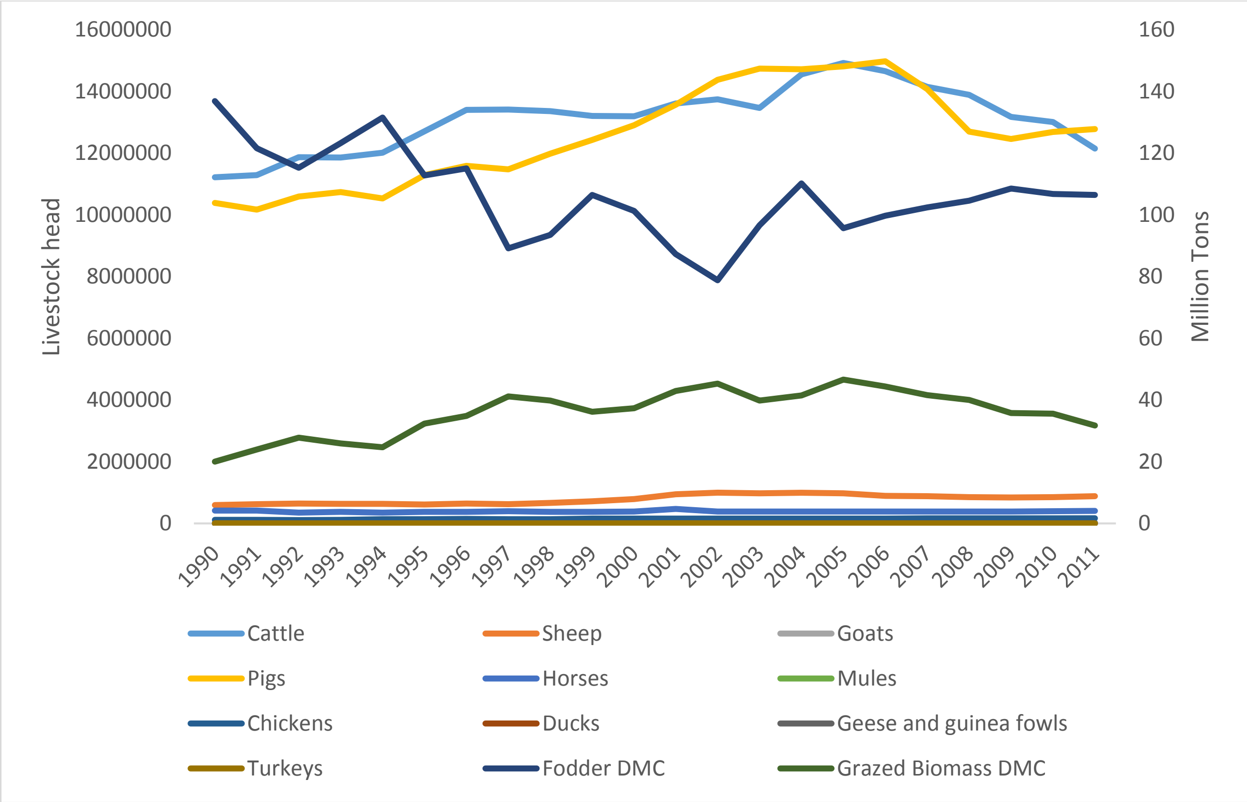



**Figure 28 i) Livestock numbers of Canada from 1990-2011 on primary axis ii) Fodder DMC and Grazed Biomass DMC for Canada from 1990-2011 on secondary axis**

On average primary crops, crop residues and forestry products constitute of 16%, 19% and 17% respectively of total domestic material consumption of Canada (Figure 29). The distribution of biomass components per annum in DMC for Canada demonstrates a similar pattern for average biomass DE category.

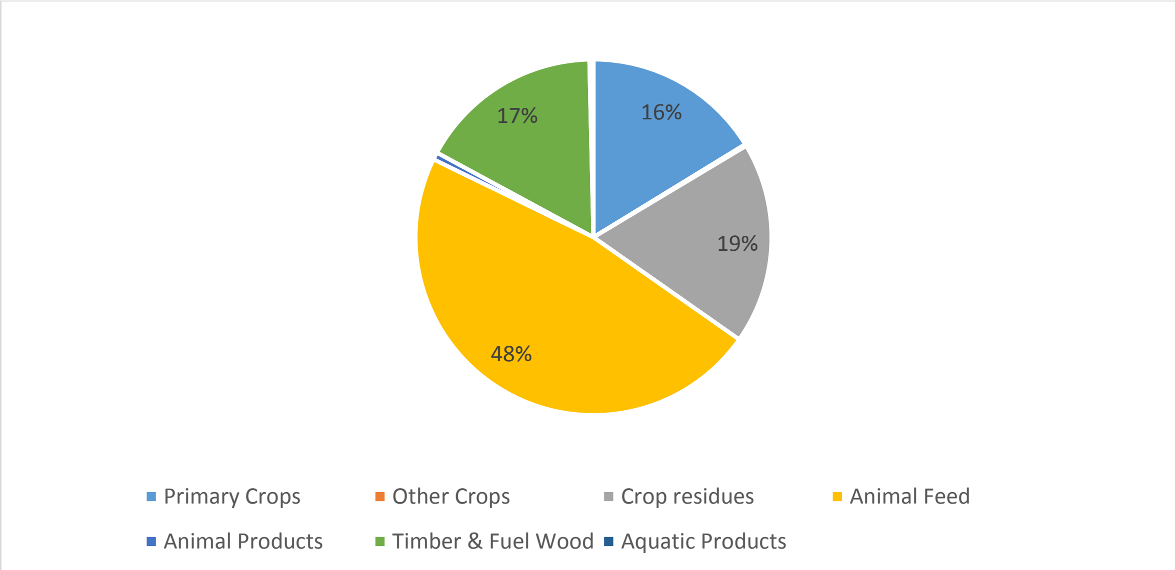



**Figure 29 Average share for DMC Biomass Components for Canada over time series 1990-2011**

Average Domestic Material Consumption of Biomass for US has been 5 times higher than of Canada, 1587 Mt from 1990-2005 as compared to Canada's 300 Mt for the same period (Figure 30). However absolute DMC for both countries has remained approximately constant since 1990, 11% increase for US and 0.22% increase for Canada. The constant DMC has impacted the DMC/capita indicator for both Canada and US with increased population of 17% each by 2005, DMC/capita has decreased by 15% and 6% respectively. Canada's DMC /capita is twice to that of US from 1990-2005. Both DMC/capita for US and Canada follows the same profile as that of DE/capita, indicating the dependence of bulk biomass consumption on domestic extraction

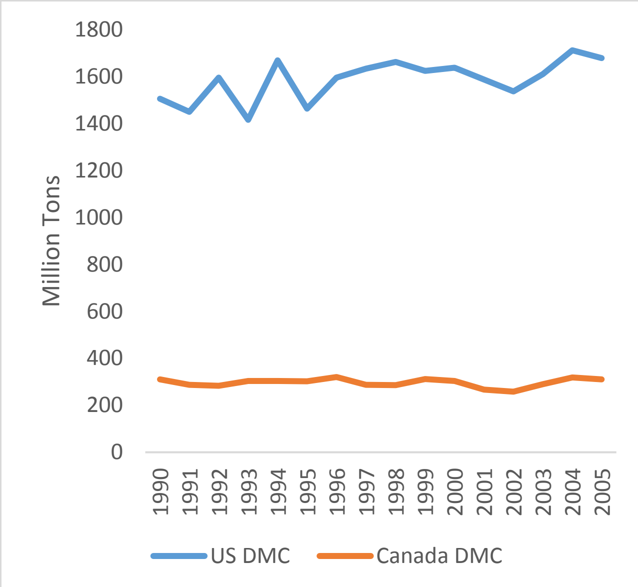



Figure 30.1

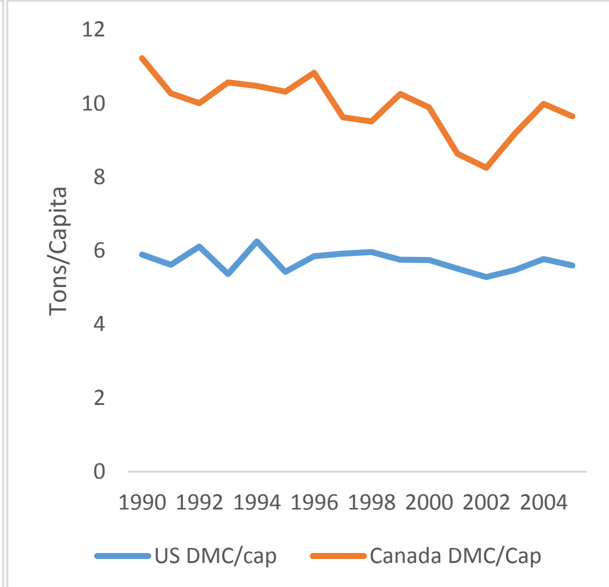



Figure 30.2

**Figure 30 Biomass Absolute DMC (29.1) and DMC/Capita (29.2) for Canada and US over time series 1990-2005**

### 4.1.5 DE to DMC ratio

DE to DMC indicator shows the dependency of the physical economy to the domestically extracted raw material. Average DE/DMC for Canada has been 1.27 from 1990-2011, which shows self-dependence of Canada for biomass (Wiesz et al., 2006). However, this may not be true for categories of fruits and vegetables where Canada imports bulk of fruit and vegetable for domestic consumption.

### 4.1.6 Physical Trade Balance

Physical Trade Balance is the difference between physical imports and exports. It allows to understand a system with respect to input and outflows as the quantity of material and leaving the economic boundary. Canada's PTB has been negative since 1990 with an average PTB per annum of -81 Mt, showing Canada as a net exporter of biomass (Figure 29).

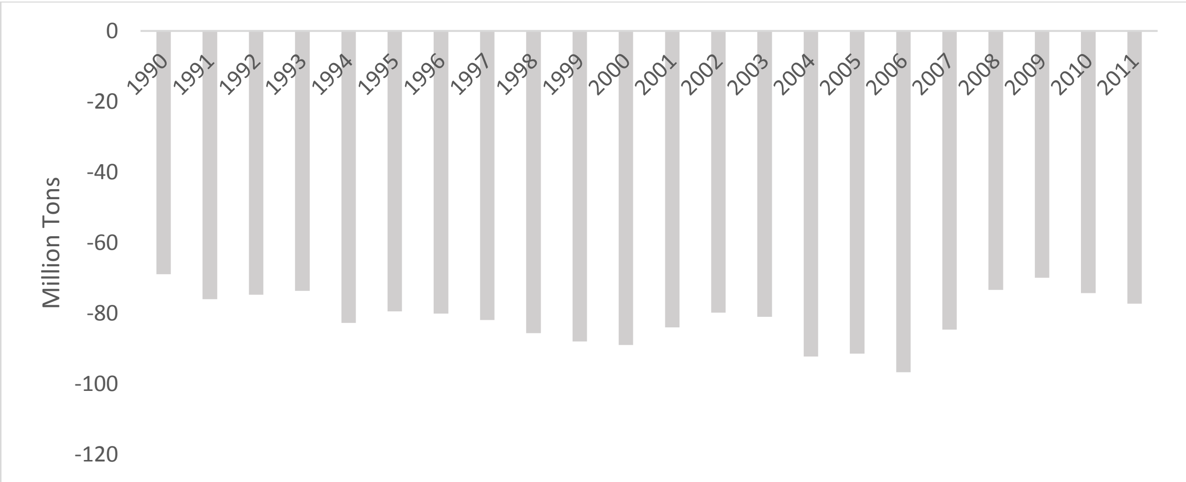
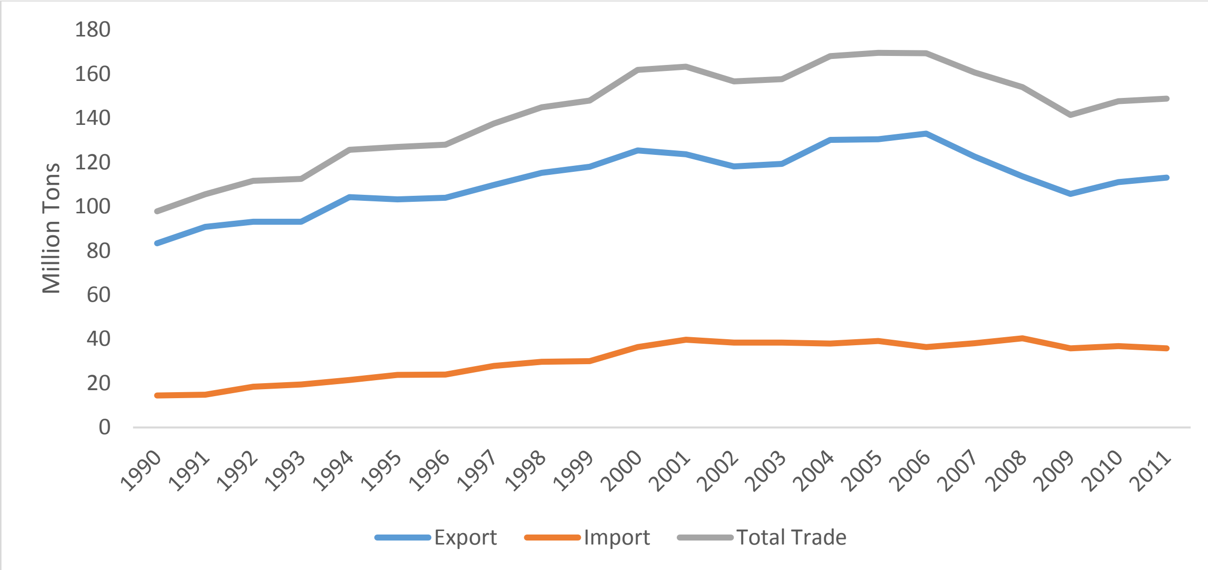



**Figure 31 Physical Trade Balance Biomass for Canada over time series 1990-2011**

The average share of physical exports in total trade i.e. aggregate of both import and exports has been 79% since 1990. Key biomass exports flows have been timber and primary crops, which together form 97% of total PTB. Even though imports grew by 150% and the share of physical exports decreased to 76% in 2011, the absolute physical quantity of exports is quite high and determines major share in total trade flows for Canada (Figure 31).




#### Figure 32 Total Trade, Physical Exports and Physical Imports Biomass for Canada over time series 1990-2011

Physical Trade Balance for both US and Canada shows the dependence of biophysical trade more towards exports. However, in recent year US biomass exports have decreased showing a shift towards imports in the PTB where imports share increased from 26% to 36% in the total trade flows (Figure 33). Whereas even though Canada's biomass exports have been increasing as compared to imports, the share of biomass imports in the total trade flows have increased from 15% to 23% during the same time (Figure 32).

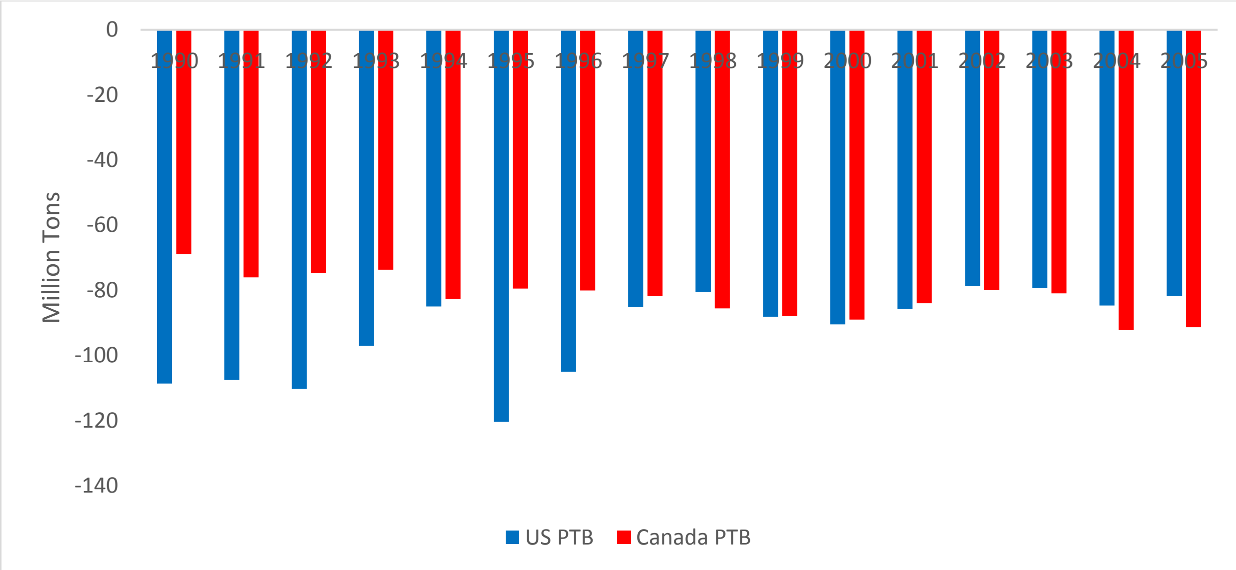



**Figure 33 Physical Trade Balance Biomass for Canada and US over time series 1990-2005**

## 4.3 Energy Flows

Canada is one of the largest producer, exporter and consumer of energy (IEA, 2017 ). To understand Canada's role in the global energy market and impact on climate change, it is important to analyze energy flows of Canada with respect to domestic extraction, import, export and domestic energy consumption. Biomass flows in this study have also been made part of the socio-economic energy flows to understand the total energy flows of the society and interaction between nature and society (Haberl, 2001a)

### 4.3.1 Domestic Extraction

Domestic Extraction is the amount of energy produced in Canada during the period of this study i.e. 1990-2011. DE includes energy extraction of coal, crude oil, natural gas, nuclear, renewables and biomass (food & feed) interpreted in terms of Peta Joules (PJ). DE for Canada has increased from 16724 PJ in 1990 to 21933 PJ in 2011, i.e. by 35% with average DE of 20508 PJ. DE for

US has been on average per annum 5 times higher than that of Canada and has been constant from 1990-2005 i.e. 97170 PJ (Figure 34). Per capita DE for Canada has been twice as compared to US and is on increasing trend each year, much because of the increasing energy exports of Canada (discussed in exports section). The per capita domestic extraction for Canada increased from 588 GJ/capita to 635 GJ per capita from 1990 to 2011, whereas that of US decreased from 386 GJ/capita to 320 GJ/capita from 1990 to 2005 majorly due in increase in imports of technical energy especially crude oil and natural gas (Figure 35).

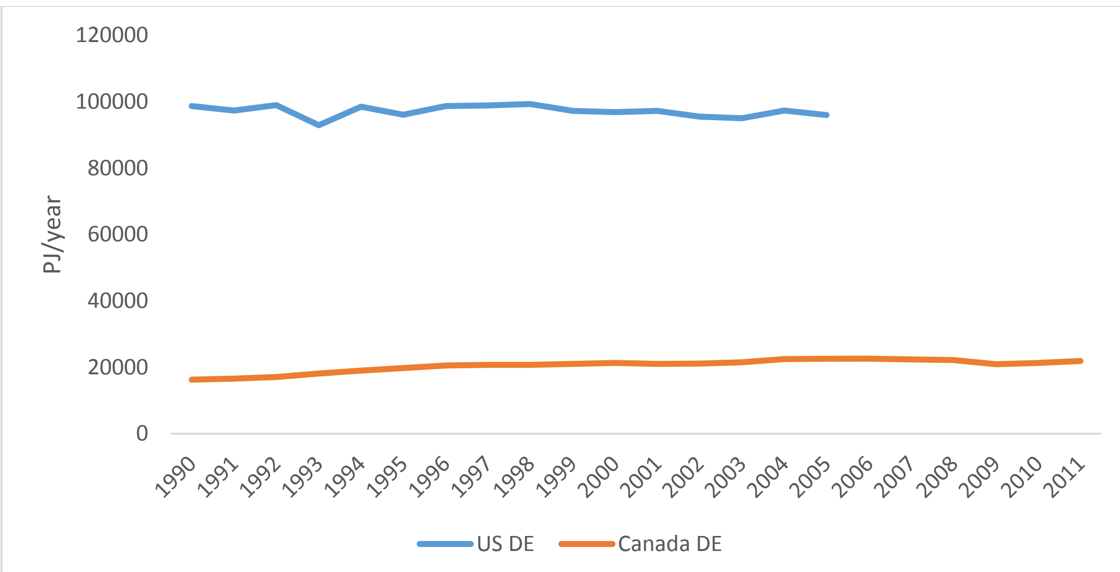



**Figure 34 Domestic Extraction Energy for Canada from 1990-2011 and for US from 1990-2005**

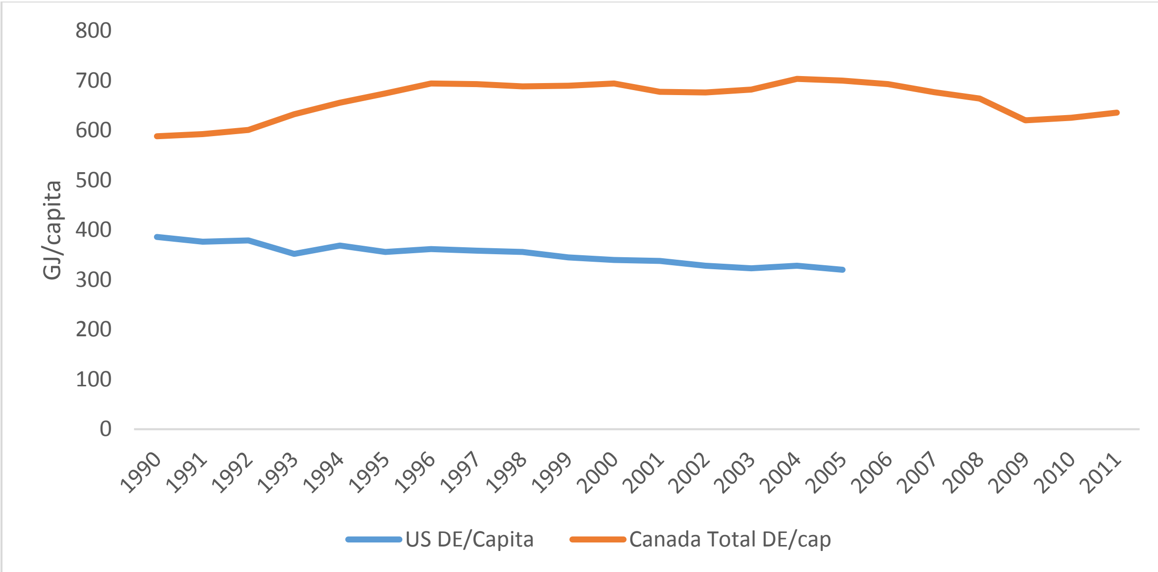



**Figure 35 Domestic extraction per capita for Canada from 1990-2011 and for US from 1990-2005**

Food & feed component of energy has remained constant for the time of the study whereas technical energy increased by 50% (Figure 36). Average DE for food & feed and technical energy has been 23% and 77% respectively, where share of food & feed decreased by 8% in 2011 and technical energy increasing its share to 80%. The shift towards technical energy in the later years shows the reliance of Canadian economy on fossil fuels, depicting an industrialized economy.

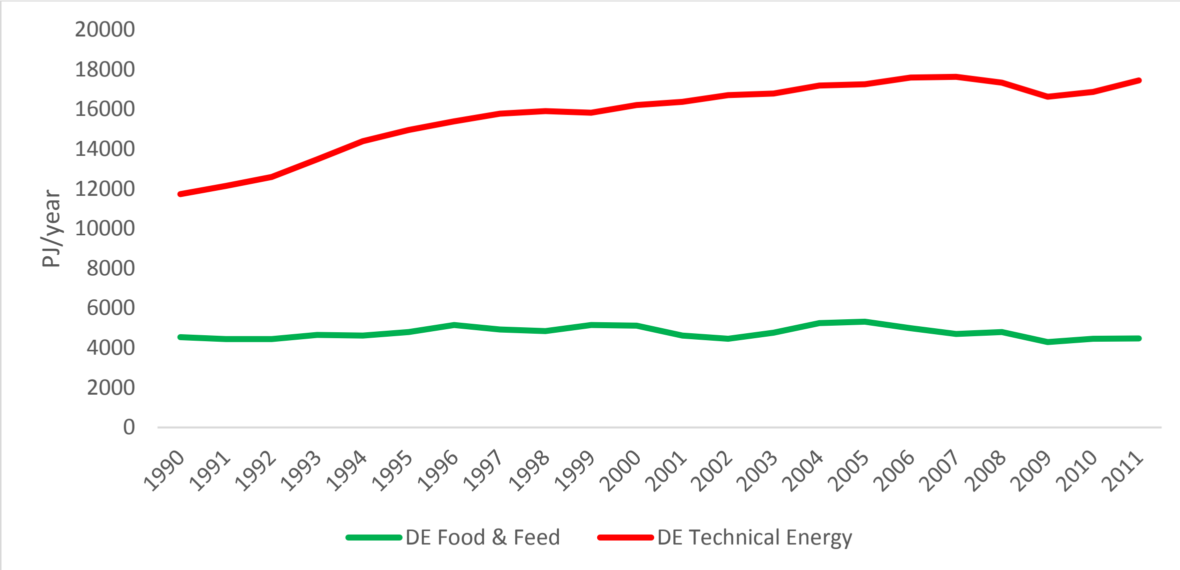



**Figure 36 Domestic Extraction Energetic Flows for Canada over time series 1990-2011**

#### 4.3.1.1 Technical Energy DE

The increase in total DE of energy has been majorly because of increase in the technical energy flows. Natural gas and crude oil production has increased by 50% and 80% respectively from 1990-2011, and they account for 31% and 28% of total domestic extraction. Food & feed (23%), renewable energy (9%), coal (8%) and nuclear energy (2%) makeup the remainder of the DE (Figure 37).

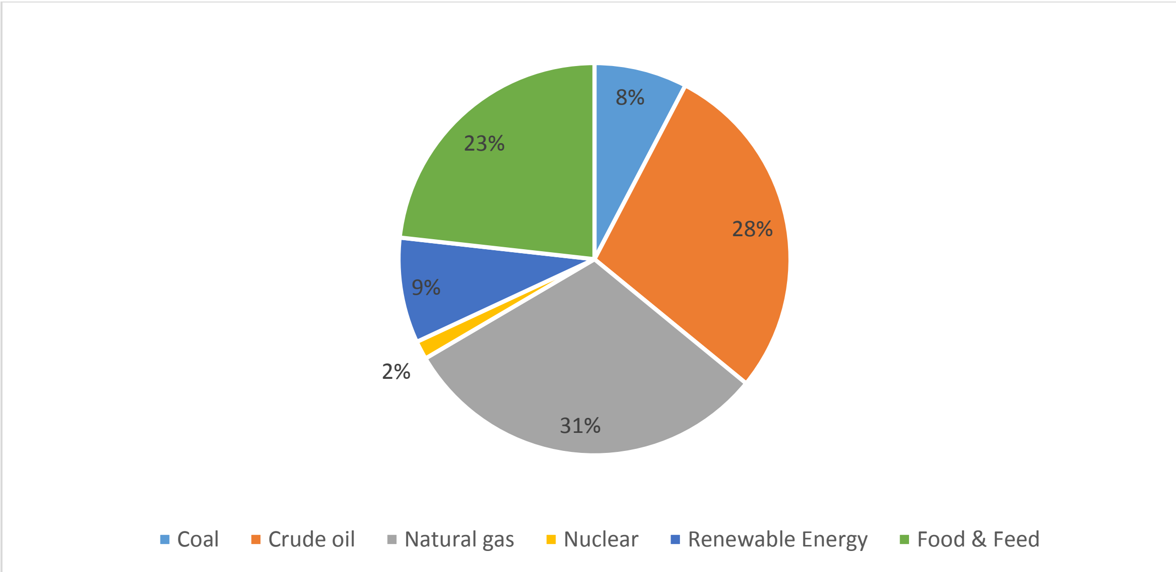



**Figure 37 Domestic Extraction Percentage Share on Average per annum Energetic Flows Categories for Canada over time series 1990-2011**

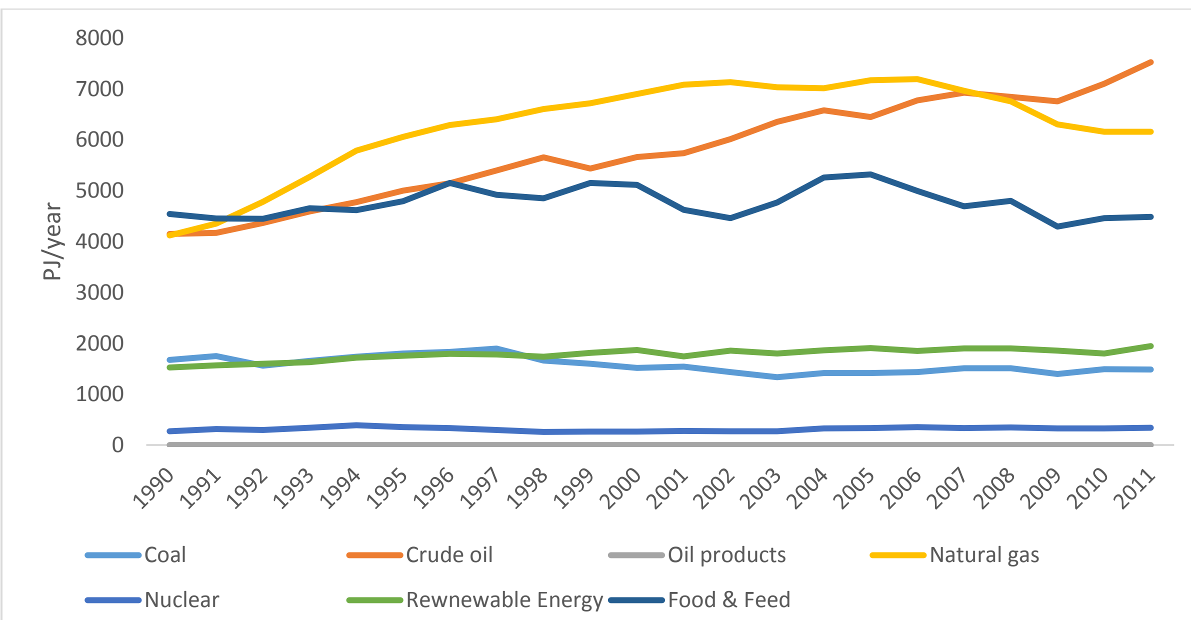



**Figure 38 Domestic Extraction Energetic Flows Categories for Canada over time series 1990-2011**

Natural Gas and crude oil form the largest energy flow for Canada from 1990-2011 as explained above. However, it is interesting to follow the trend of domestic extraction for both during the same period. Natural gas was increasing at the rate 3.24% each year till 2006 going to a maximum of 7193 PJ, before dropping off to its lowest value of 6198 PJ since 1995 (Figure 38). A major reason for drop in the production of natural gas has been decline in imports by the US due to own production (STATCAN, 2007). On the other hand, crude oil production is continuously increasing at the rate of 2.74% since 1990 surpassing natural gas energy production in 2007 (Figure 38) and has remained the biggest domestic extraction energy flow for Canada since then.

#### 4.3.1.2 Food & Feed Energy DE

Food & feed has been the third largest flow with a share of 23% of the total energy domestic extraction of Canada from 1990-2011, increasing at a rate of 0.02% per annum. Timber and primary crops have been the largest energy contributors towards food & feed, accounting for 40% and 24% of the total domestic extraction. Animal feed i.e. animal grazing and fodder crops make up 20% of the total domestic extraction and crop residues constitute of the remaining 15% (Figure 39). Like discussed in the biomass section of the results, domestic extraction of timber started decreasing from 2004 going to the lowest point since 1980's in 2009 majorly due to lumber crisis with the US and increasing since 2010. Primary crops have been increasing at the rate of 0.8% per annum with cereals being the major part of the domestic extraction energy flow. Crop residues follow the same pattern as 95% of crop residues comes from straw whereas animal feed increasing at the rate of 0.7%.

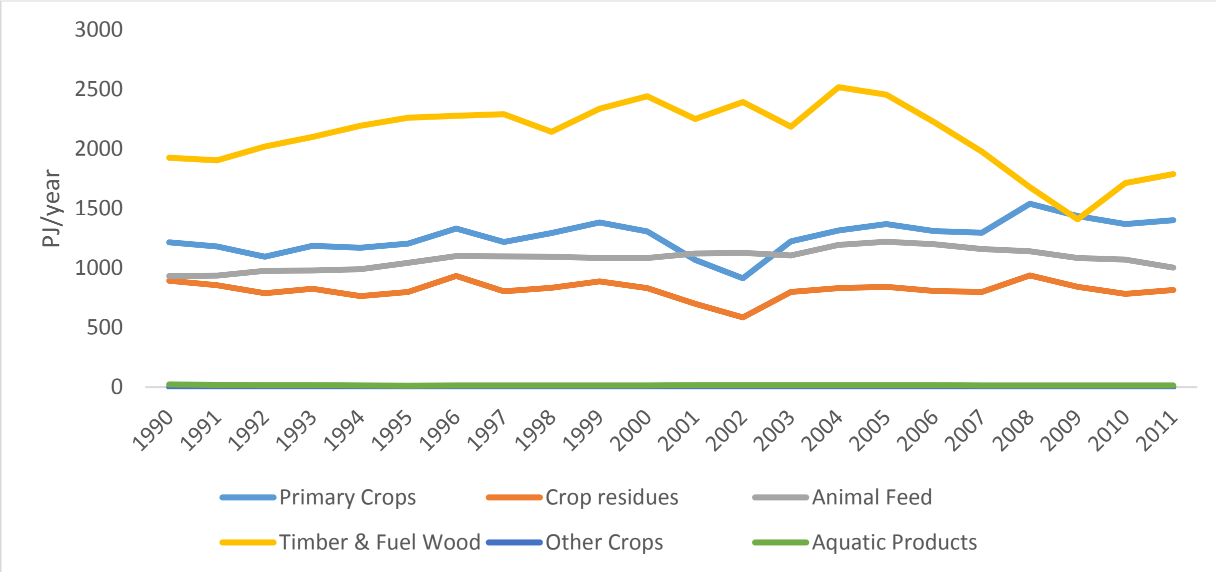



**Figure 39 Domestic Extraction Energetic Flows Categories of Food & Feed for Canada over time series 1990-2011**

#### 4.3.1.3 Renewable Energy DE

Renewable energy which includes hydro, solar geothermal and biomass fuel has been growing at the rate of 0.8% and forms 8% of the average domestic extraction from 1990-2011. Non-renewable energy has the largest share of energy flows in Canada and is increasing by every year, whereas food & feed's share is decreasing, and renewable energy's share is constant (Figure 40).

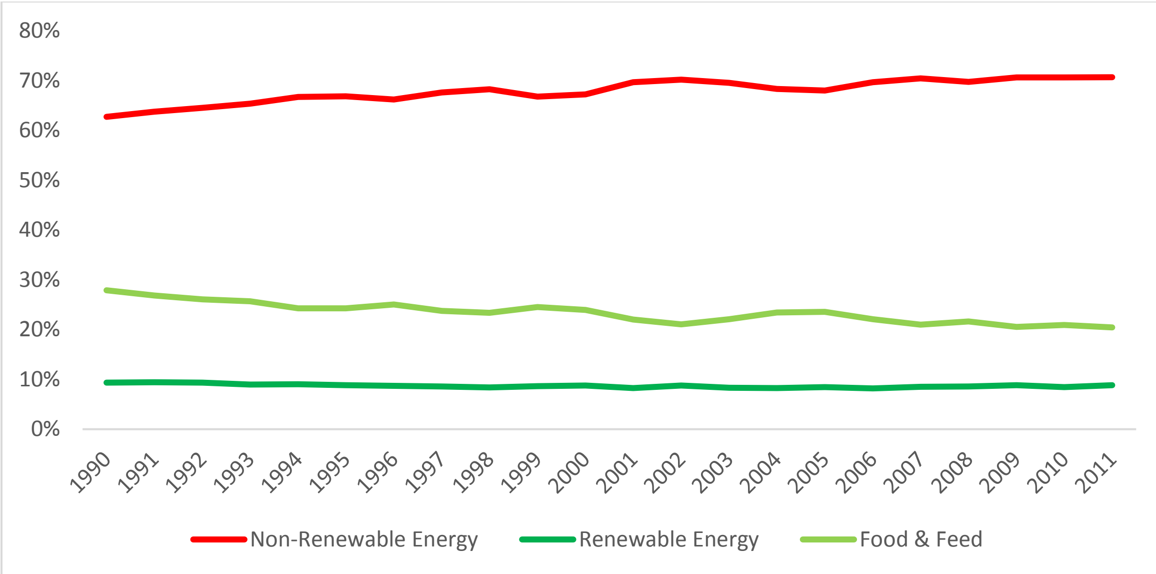



**Figure 40 Annual Share of Domestic Extraction Energetic Flows Categories for Canada over time series 1990-2011**

Largest renewable energy flow in Domestic Extraction for Canada is hydro which forms 70% of the renewable energy DE i.e. 1239 PJ/year (Figure 41). 29% of the remaining renewable energy DE is from biofuels and waste i.e. 535 PJ/year on average (Figure 41). Average DE of solar, geothermal and wind power is quite low i.e. 0.03% but has increased to 0.18% in 2011. Even though hydro and biofuels & waste appear to be large flows of energy in domestic extraction of renewable fuels, they only contribute 7.95 and 3.4% to total technical energy domestic extraction, and 6% & 2.6% of the total DE of energy flows of Canada.

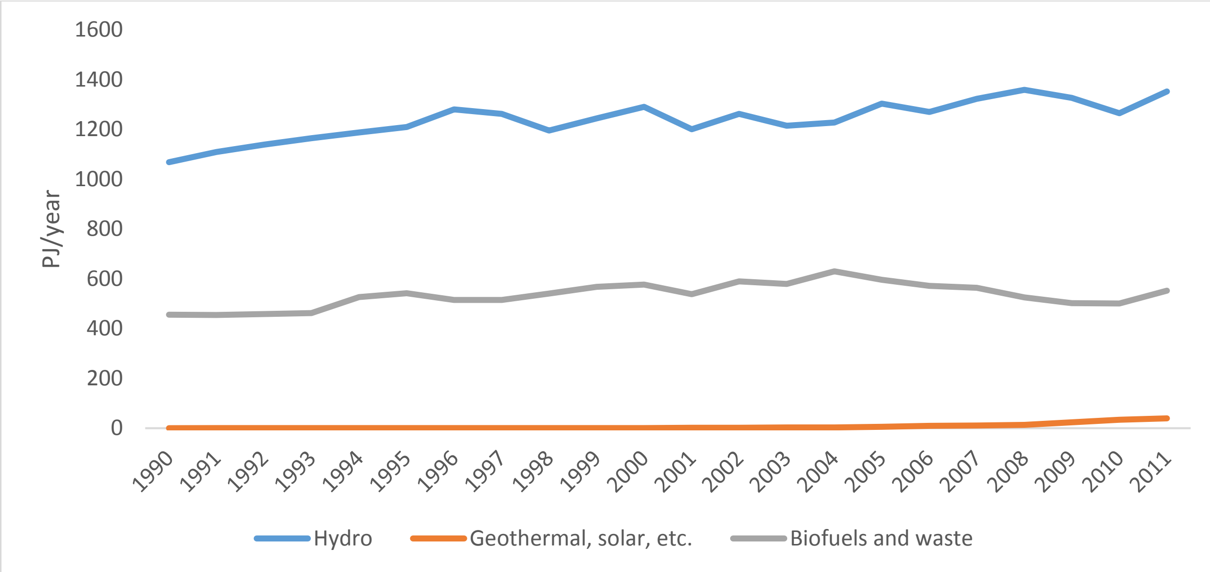



**Figure 41 Domestic Extraction Energetic Flows Categories of Renewable Energy for Canada over time series 1990-2011**

## 4.3.2 Imports and Direct Energy Input

Imports are the physical quantities of energy carriers entering the economic boundary of Canada from other economies. Average energy imports for Canada i.e. technical energy import and food & feed energy import has been 3393 PJ from 1990-2011. As compared to 1990, the energy imports for Canada have increased by 100% i.e. from 2223 PJ in 1990 to 4380 PJ in 2011. Physical Imports of US have been 9.6 times of Canada from 1990-2005 and have increased by 86% during the same time period. Average imports per capita for both countries are similar and is 104 GJ/capita for US from 1990-2005 and 108 GJ/capita for Canada from 1990-2011. Major import for US has been crude oil which forms 82% of the total energy imports.

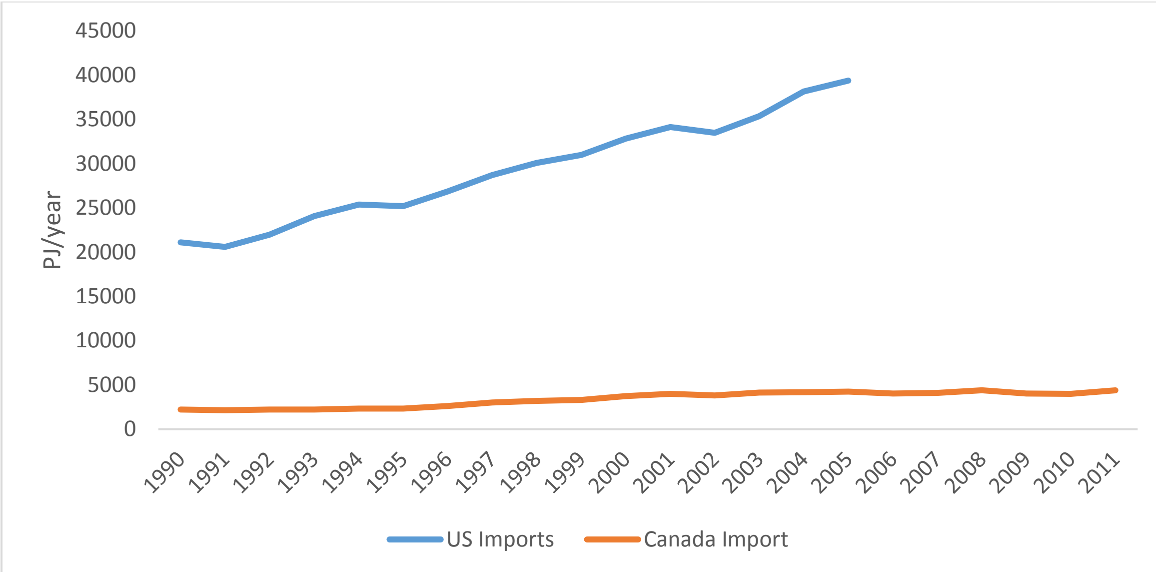



**Figure 42 Energy Imports for Canada from 1990-2011 and for US from 1990-2005**

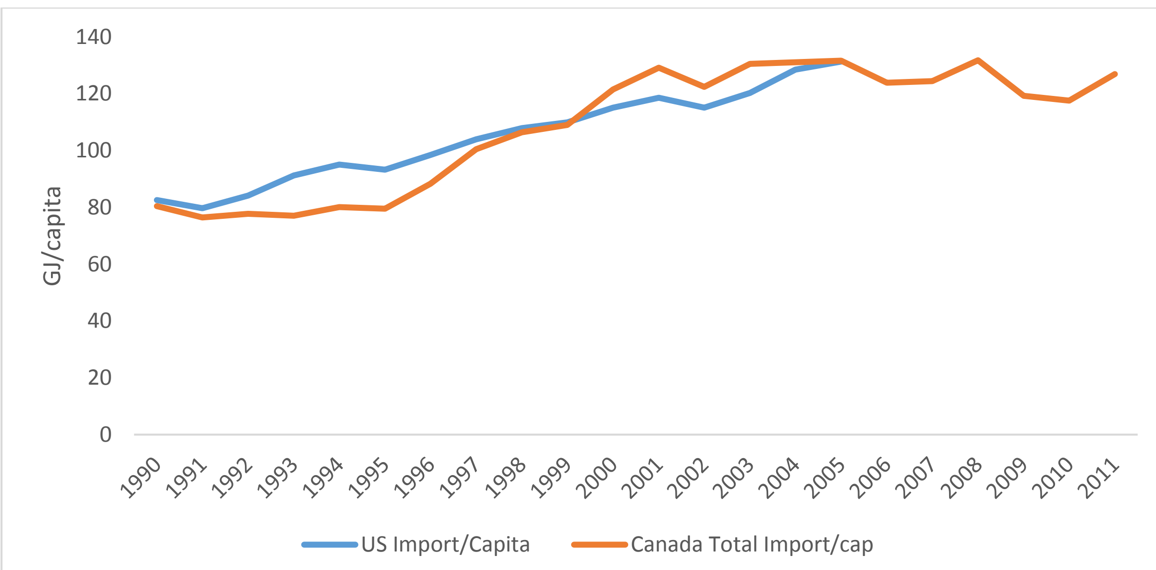



**Figure 43 Energy Imports per capita for Canada from 1990-2011 and for US from 1990-2005**

The average share in energy imports for food & feed and technical energy has been 13% and 87% respectively. Technical energy imports have increased by 89%, increasing at a rate of

3.72% per year since 1990 whereas food & feed increased by 184% increasing at a rate of 5% (Figure 44). Over all energy imports have increased at the rate of 3.88% per year.

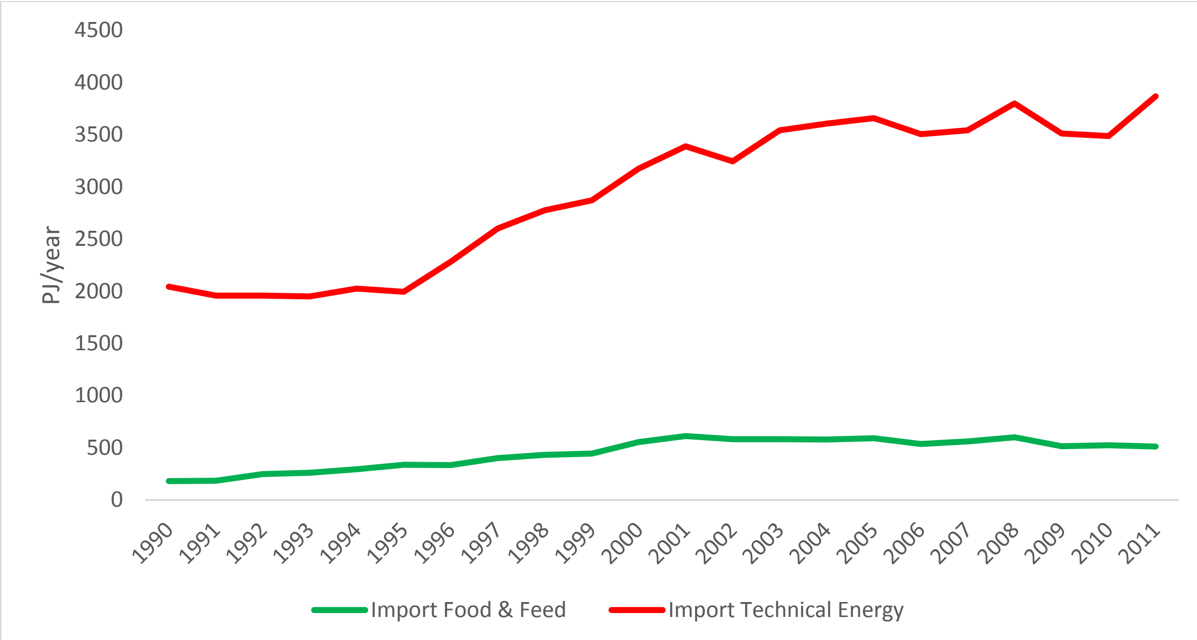



Figure 44 Energy Imports for Canada over time series 1990-2011

#### 4.3.2.1 Technical Energy Imports

Crude oil has been the largest import of Canada since 1990 constituting of 50% of the average energy imports. Coal, food & feed and oil products share 13% each and natural gas accounts for 8% in the total energy imports of Canada (Figure 45).

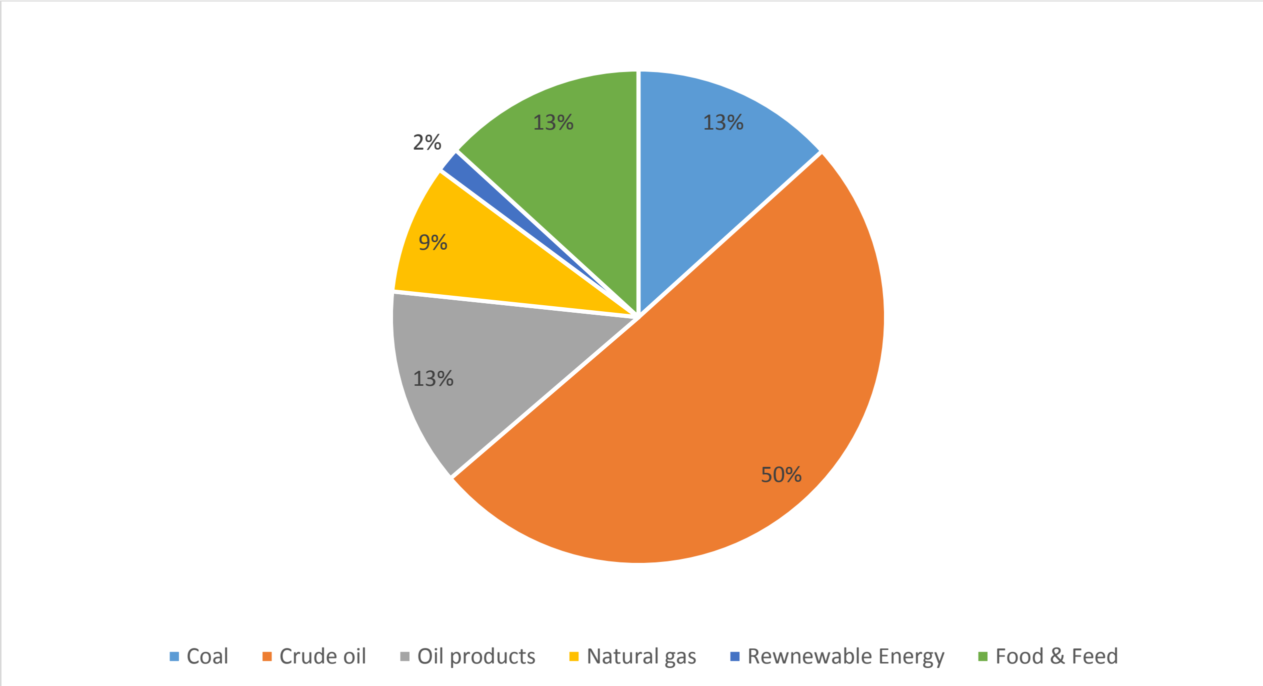



**Figure 45 Imports Percentage Share on Average per annum Energetic Flows Categories for Canada over time series 1990-2011**

By 2011, Crude Oil imports increased by 37% as compared to that of 1990 i.e. from 1195 PJ 1646 PJ, but there have been variations in the import of crude oil (Figure 46). Crude oil imports increased at the rate 5.8% per annum from 1990 to 2000, reaching highest point in the period of this study i.e. 2069 PJ. The import of crude oil kept fluctuating between 2000 PJ and 1800 PJ till 2008 and dropping to lowest point since 1996 to the value of 1646 PJ in 2011, mainly due to high domestic extraction and exports from Canada. Oil products imports have increased to 668 PJ in 2011 and have been on an increasing trend since 1990 whereas coal imports on the other hand have been declining since 2001, reaching its lowest point of 289 PJ in 2011. The largest import increase in recent years has been in natural gas where the share of natural gas in total energy imports of Canada increased from 13% in 2007 to 28% in 2011 i.e. from 516 PJ to 1208 PJ, largely due to import of cheaper natural gas from US for Ontario and Quebec (Cowan, 2011).

Also, the average rate of increase of imports of natural gas from 1990 to 2001 was 10% whereas it increased to 20% from 2002 to 2011.

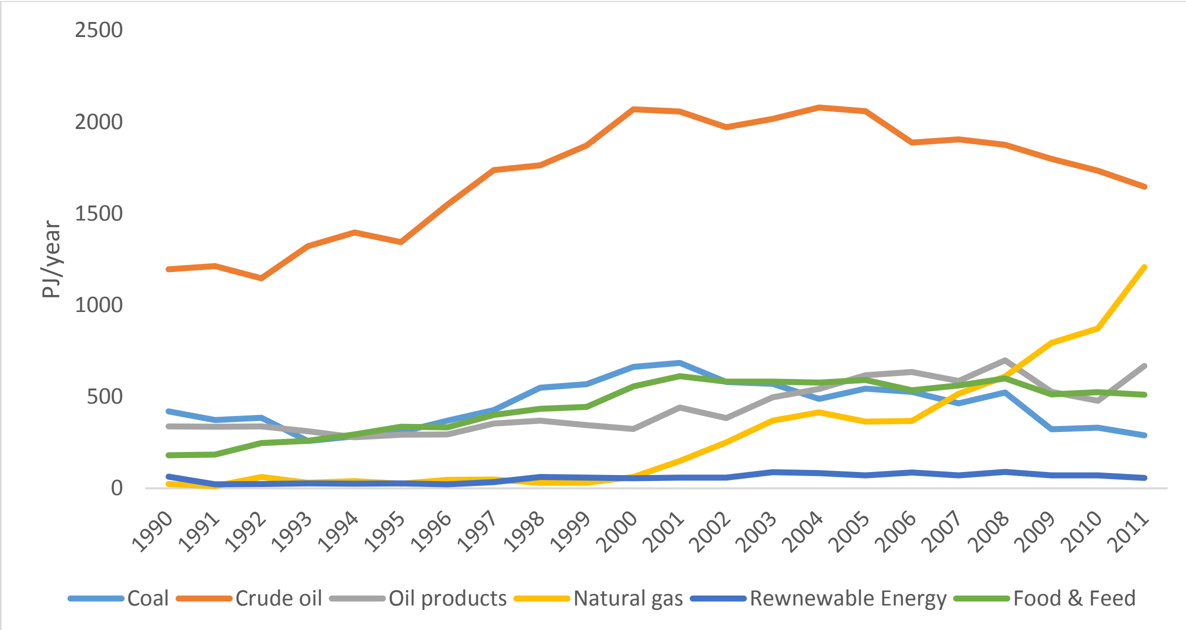



**Figure 46 Energy Imports Categories for Canada over time series 1990-2011**

#### 4.3.2.2 Food & Feed Energy Imports

Food & feed accounts for 13% of the total energy imports of Canada. Food & feed energy imports have been growing since 1990, reaching maximum value of 612 PJ in 2001 i.e. 3.5 times more than the value in 1990 which was 180 PJ. Increasing at an average rate of 5.1% per annum, food & feed energy value for 2011 was 511 PJ (Figure 46). Timber and primary crops form the largest share of food & feed energy imports from 1990-2011 i.e. 62% and 24%. Imports for timber reached its highest value by 2005 i.e. 391 PJ before going down to 288 PJ, the lowest since 1997(Figure 47). However, in recent year's share of timber imports have gone down to 56%. Overall the timber energy imports increased from 91 PJ in 1990 to 288 PJ in 2011. Average imports of primary crops during the same period is 108 PJ. Cereals, oil bearing crops and fruits share 48%, 20% and 17% of the primary crop imports (Figure 47). One important factor is to note about other crops i.e. tobacco, spices, stimulants (tea etc.) and alcoholic beverages, is the increasing trend since 2009 with almost 3 times the increase in imports of tobacco and alcoholic beverages.

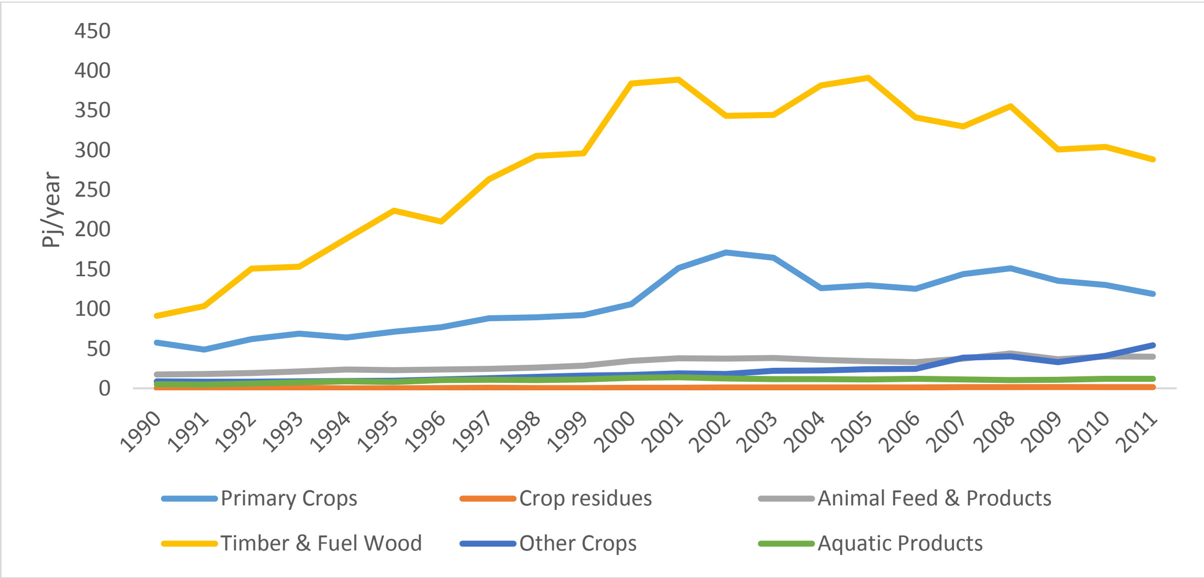



**Figure 47 Import Energy Flows Categories of Food & Feed for Canada over time series 1990-2011**

#### 4.3.2.3 Renewable Energy Imports

Average imports for renewable energy have been 1.6% of the total energy import for Canada from 1990-2011. Renewable energy imports have been varying over the period of this study with an average per annum of 55.7 PJ, a maximum value of 88 PJ in 2003 and a lowest point of 22 PJ in 1996 (Figure 48). For 2011 the renewable energy imports was 57 PJ, accounting for 1.3% of the total energy import flow and 1.5% of the total technical energy import. The huge difference between the imports of renewable energy and non-renewable energy requires further explanation and will be discussed in the discussion chapter of the thesis.

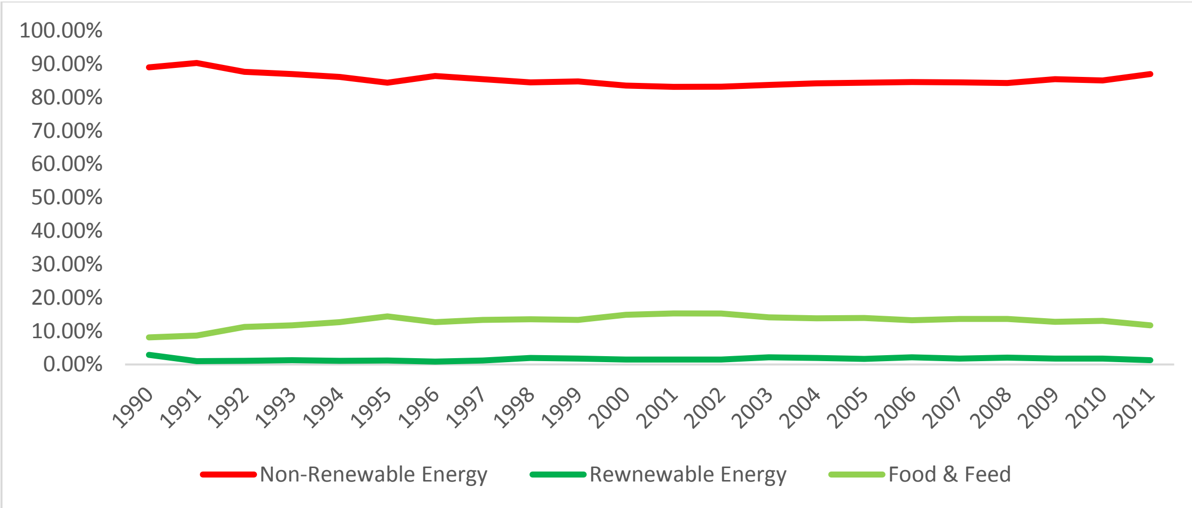



**Figure 48 Percentage of Import Energy Flows Categories for Canada over time series 1990-2011**

#### 4.3.2.4 Direct Energy Input

Direct Energy input is the sum of domestic extraction and import energy flows. It identifies the physical amount of energy entering the system. Average DEI for Canada has been 23902 PJ from 1990-2011 with an increase of 42% (Figure 49). DEI and DE follow the same pattern and DEI depends largely on DE as DE shares 86% of DEI. However, the share of imports in DEI has increased to 17% in 2011. The biggest contributors towards direct energy input have been crude oil and natural gas i.e. 31% and 27% respectively. The total share of non-renewable energy in DEI has been 71%, whereas for food & feed and renewable energy has been 22% and 7% respectively (Figure 50).

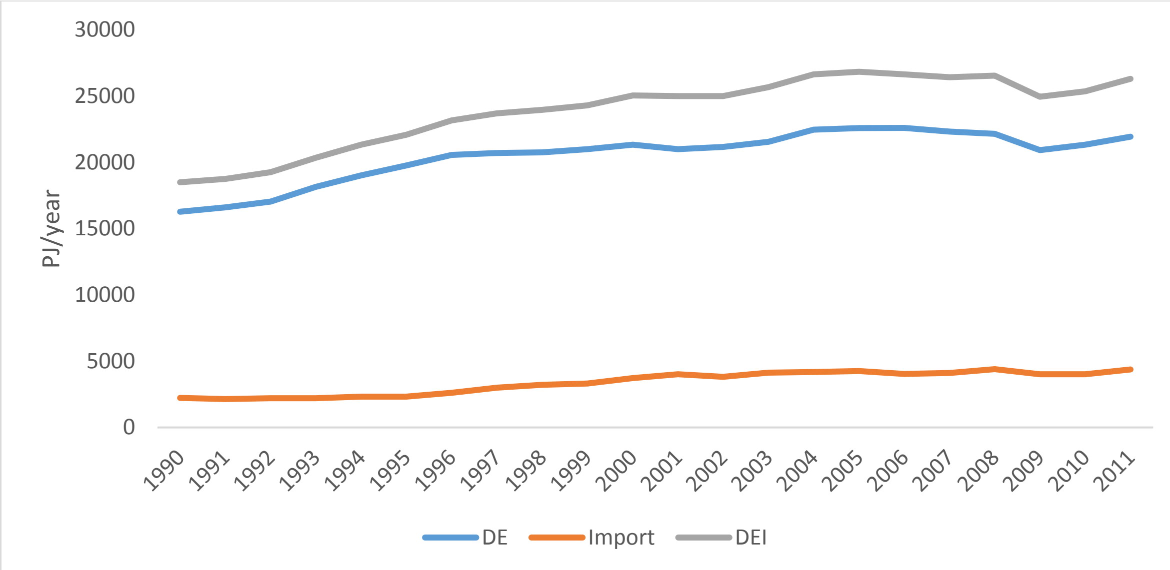



**Figure 49 Energy DEI, DE and Physical Imports for Canada from 1990-2011.**

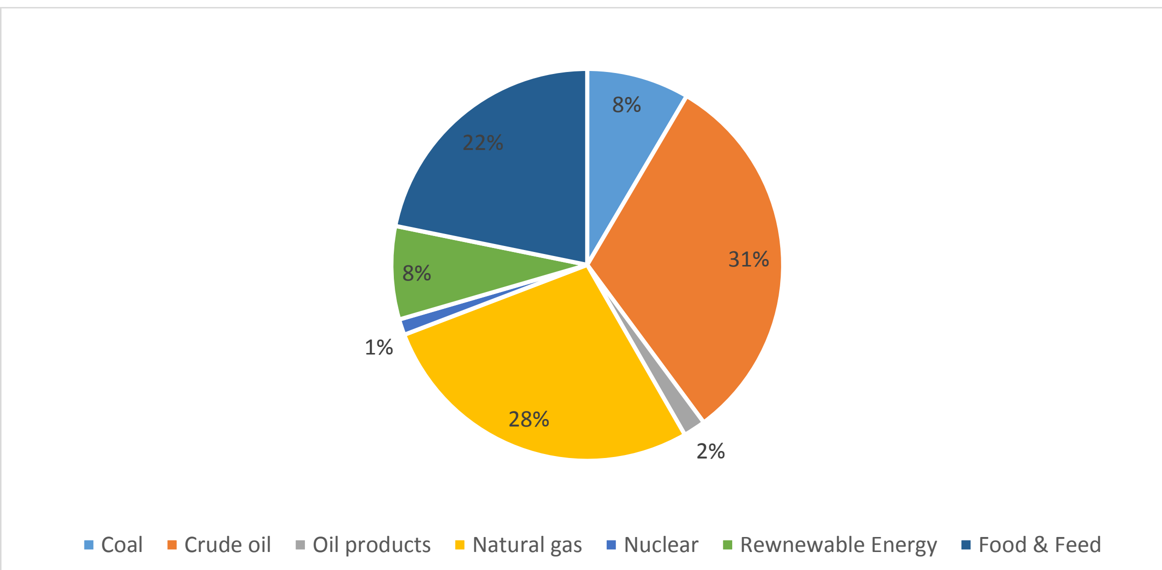



**Figure 50 Average Direct Energy Input by categories for Canada from 1990-2011**

### 4.3.3 Exports

Exports account for the physical exports of energy from Canada to ROW. Average energy export for Canada from 1990-2011 has been 10583 PJ. Exports have been increasing at the annual rate of 3% with minimum value of 6275 PJ in 1990 to a maximum value of 12778 PJ in 2011, an increase of 100% (Figure 51). In contrast to Domestic Extraction and Physical Energy Imports, Physical Exports of US on average have been 1.4 times less to that of Canada from 1990-2005. Since 1993 Canada's energy exports have been higher than that of US and increasing every year especially that of non-renewable energy, whereas energy exports of US have been constant (Figure 51). Energy export/capita for Canada is 12.5 times higher than that of US and has increased from 227 GJ/capita in 1990 to 370 GJ/capita in 2011, whereas export/capita for US decreased from 30 GJ/capita to 26 GJ/capita from 1990-2005(Figure 52).

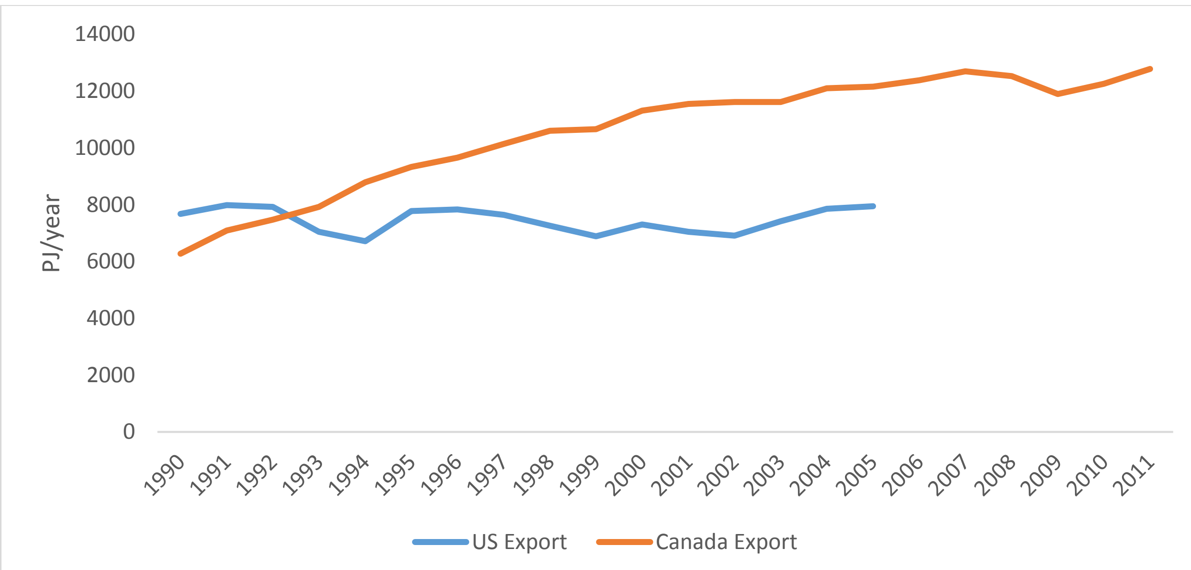



**Figure 51 Energy exports for Canada from 1990-2011 and for US from 1990-2005**

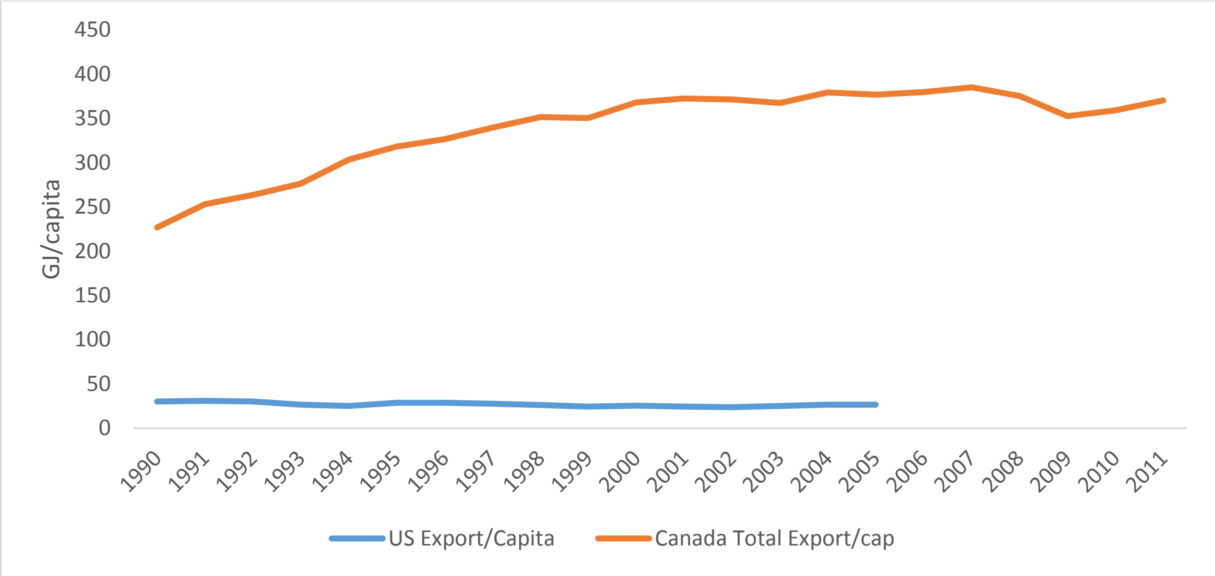



**Figure 52 Energy exports/capita for Canada from 1990-2011 and for US from 1990-2005**

Average energy exports of Canada largely consist of technical energy exports which forms 80% of the total energy exports and have been increasing at the rate of 3.36%. Average technical energy exports have been 8534 PJ with a minimum value of 4737 PJ in 1990 and a maximum value of 10731 PJ in 2011, an increase of 126%. Food & feed energy exports have increased by 33% for the period of this study, however the share of technical energy in the total energy exports has increased i.e. from 75% in 1990 to 84% in 2011 (Figure 53).

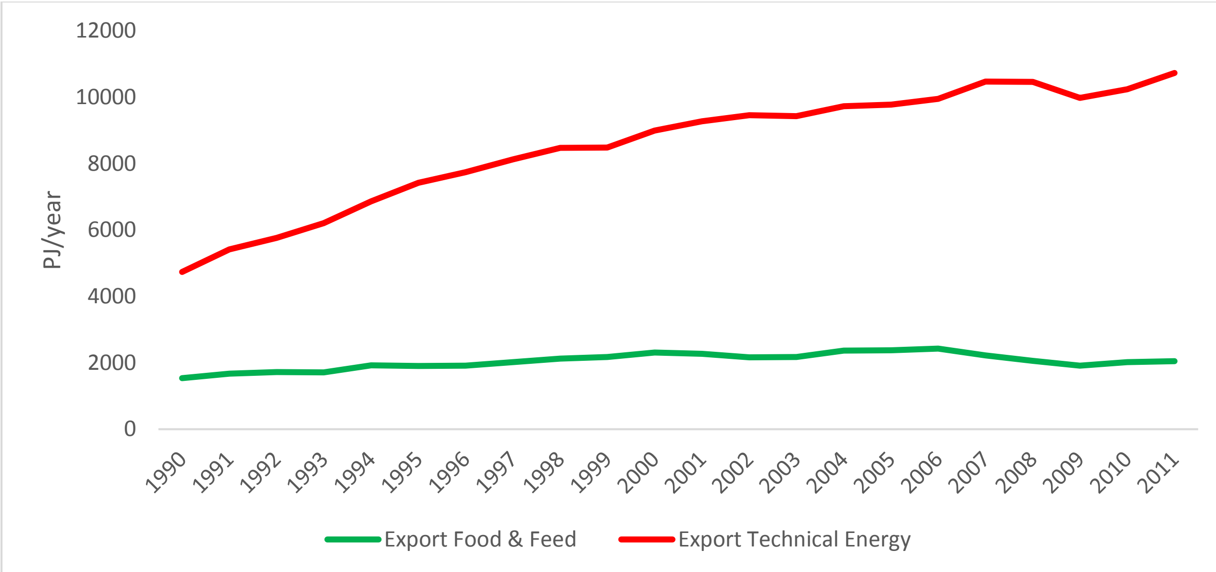



**Figure 53 Energy Exports for Canada over time series 1990-2011**

#### 4.3.3.1 Technical Energy Exports

Natural gas and crude oil have been Canada's largest energy exports from 1990-2011. Total energy exports of Canada for the period of this study comprises 32% crude oil exports and 31% natural gas exports. Food & feed, coal, oil products and renewable energy form 19.5%, 8.1%, 7.2% and 1.5% respectively of the energy exports (Figure 54).

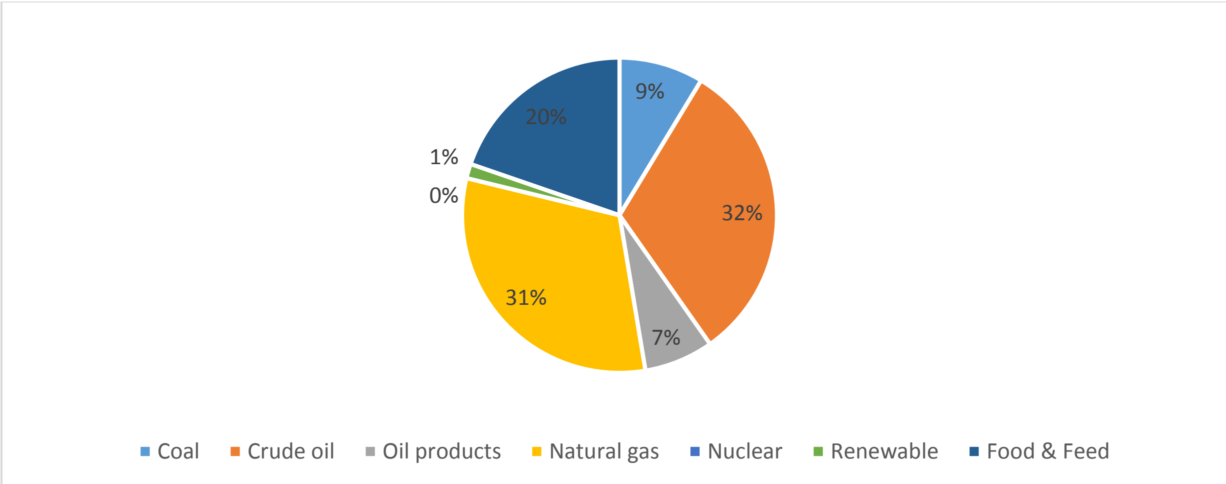



**Figure 54 Exports Share on Average per annum Energetic Flows Categories for Canada over time series 1990-2011**

Exports of crude oil have increased by 213% at a rate of 4.7% increase per annum since 1990 i.e. from 1666 PJ in 1990 to 5223 PJ in 2011, whereas the exports of natural gas increase by 133% at a rate of 3.5% i.e. from 1537 PJ in1990 to 3575 PJ in 2011(Figure 55). The crude oil exports from 1990-2011 were continuously increasing and surpassed the share of natural gas exports in the total exports of Canada in 2006. Export of natural gas has declined since 2007 i.e. from 4148 PJ in 2007 to 3575 PJ in 2011(Figure 55). Coal exports share 8.2% of the total energy exports of Canada i.e. 867 PJ which shows the same trend as of DE of coal, pointing towards Canada's plan to eliminate coal as a source of energy (NRCAN, 2017). Oil products form 7% and have increased by 67% from 1990-2011, however their absolute value is of little significance.

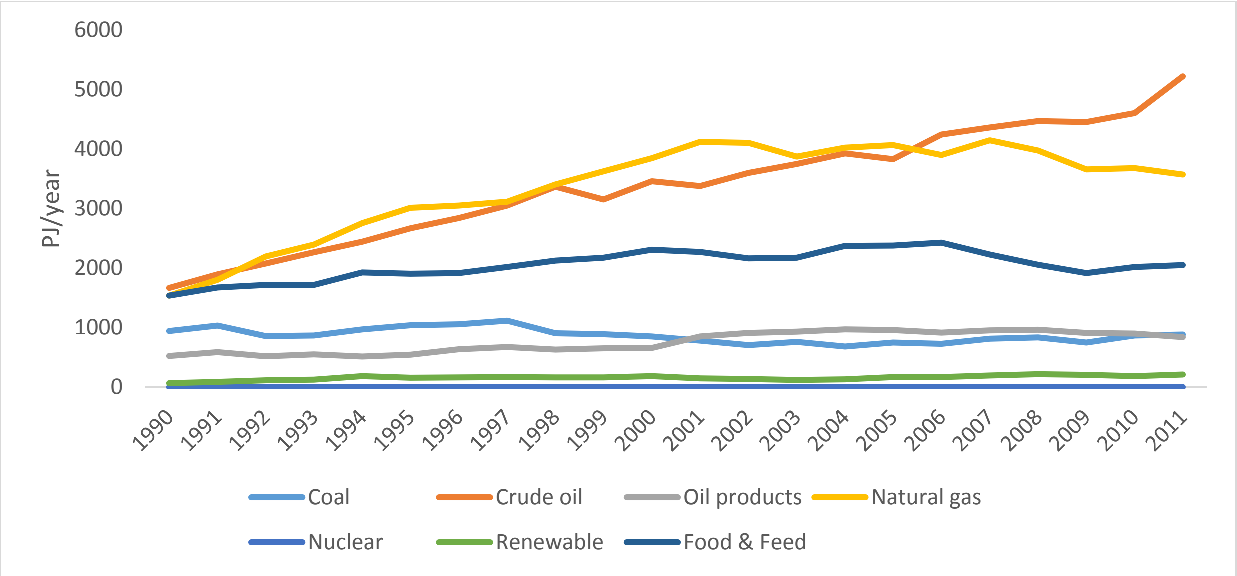



**Figure 55 Energy Exports Categories for Canada over time series 1990-2011**

### 4.3.3.2 Food & Feed Energy Exports

Food & feed amounts for 19% of the average energy exports of Canada from 1990-2011. The exports of food & feed energy increased by 33%, however the export energy value followed a roller coaster ride i.e. exports increased from 1537 PJ in 1990 to 2437 PJ in 2006 and dropping off to 1917 PJ in 2009 and increasing again to 2048 PJ in 2011 (Figure 56). This variation in the exports of food & feed energy has been largely due to timber exports from Canada to US (Couture & Macdonald, 2012). Food & feed energy in the total energy exports of Canada has been decreasing since 1990, showing Canada's energetic metabolism depending on the exports of fossils fuels in the recent years. Timber and primary crops form the major exports of food & feed, i.e. 64% and 31%. The export of timber increased from 963 PJ in 1990 to 1693 PJ in 2004, falling off to 997 PJ in 2009 and increasing again to 1147 PJ in 2011.Average exports for primary crops during the same period is 643 PJ (Figure 56), as cereals, oil bearing crops and pulses sharing 68%, 23% and 7% respectively.

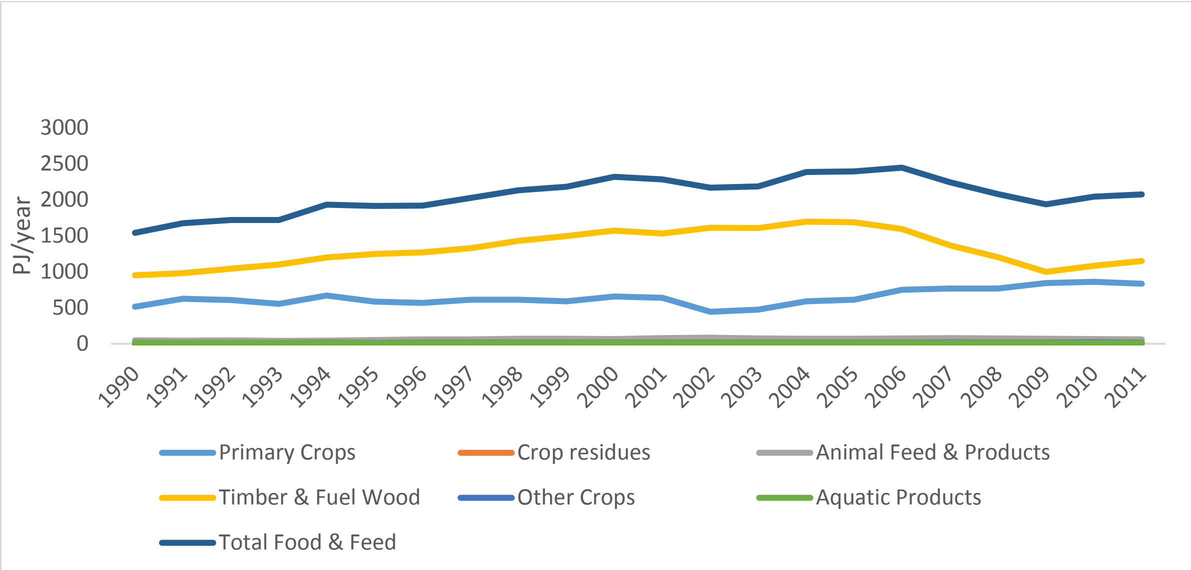



**Figure 56 Export Energy Flows Categories of Food & Feed for Canada over time series 1990-2011**

#### 4.3.3.3 Renewable Energy Exports

Renewable energy exports contribute a very small amount to the total energy exports of Canada from 1990-2011 i.e. 1.5% (Figure 57). Though the value of renewable energy exports has increased from 66 PJ in 1990 to 209 PJ in 2011, reaching a peak value of 217 PJ in 2008, the share of renewable energy in total energy exports has remained between 1% and 1.5% for the period of this study Major renewable energy export is electricity from hydro which is 96% of the total renewable energy export.

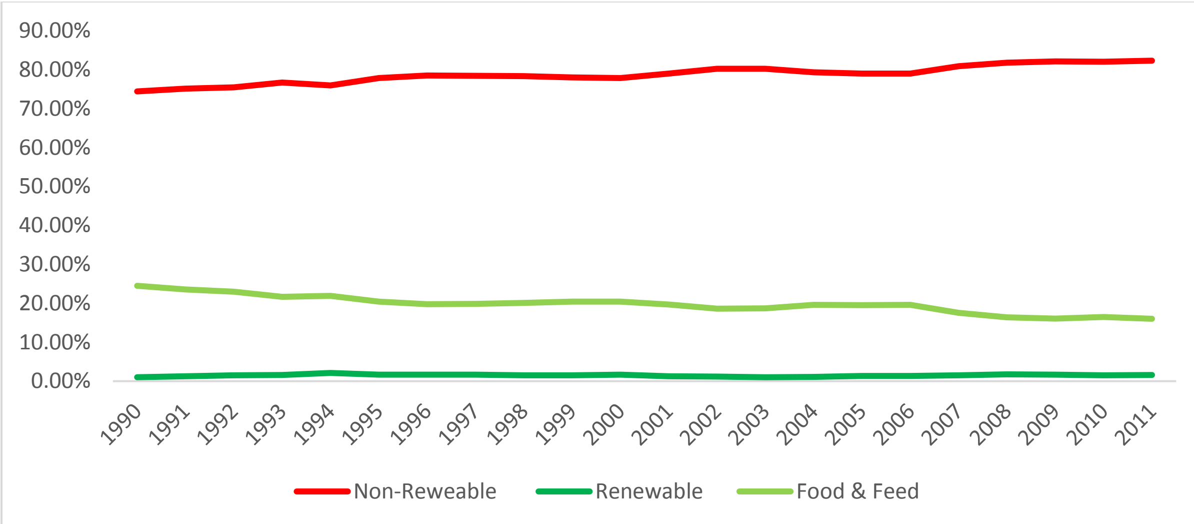



**Figure 57 Percentage Representation of Import Energy Flows Categories for Canada over time series 1990-2011**

### 4.3.4 Domestic Energy Consumption

Domestic Energy Consumption is the difference between Direct Energy Input and Exports or in other words can be shown as DEC = DE + Imports – Exports. Average DEC of Canada has been 13319 PJ from 1990-2011 with a maximum value of 14677 PJ in 2005 and a minimum value of 11772 PJ in 1992 (Figure 58). The gap between DEC and energy exports has been reducing with each year passing, with share of DEC being 51% and of Exports 49% of the total DE in 2011 as compare to 66% and 34% respectively in 1990. The growing share of exports shows that the DE is increasing majorly because of Canada's economy depending on high energy exports as DEC has remained constant for the period of this study.

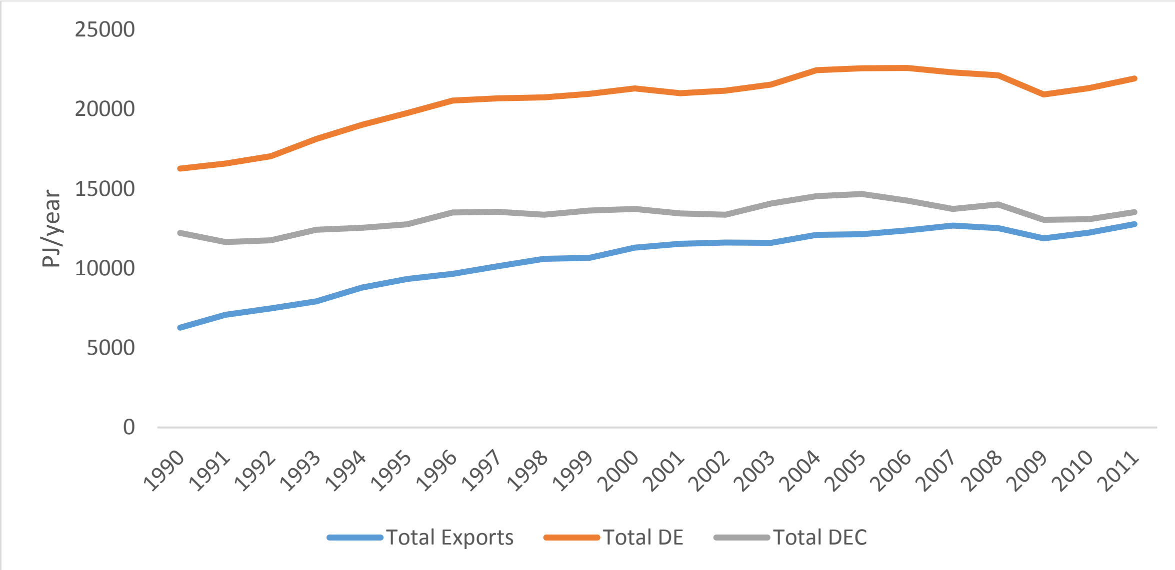



**Figure 58 DEI, DEC and Energy Exports for Canada from 1990-2011**

80% of average DEC consists of non-renewable and renewable energy for Canada, the remaining 20% belongs to food & feed (Figure 59). Crude oil, natural gas, coal and nuclear energy share 65% of the total DEC, indicating the societal energy consumption to be dependent on fossil fuel energy sources. Renewable energy consumption has increased since 1990 but remained constant from 2000 (Figure 59).

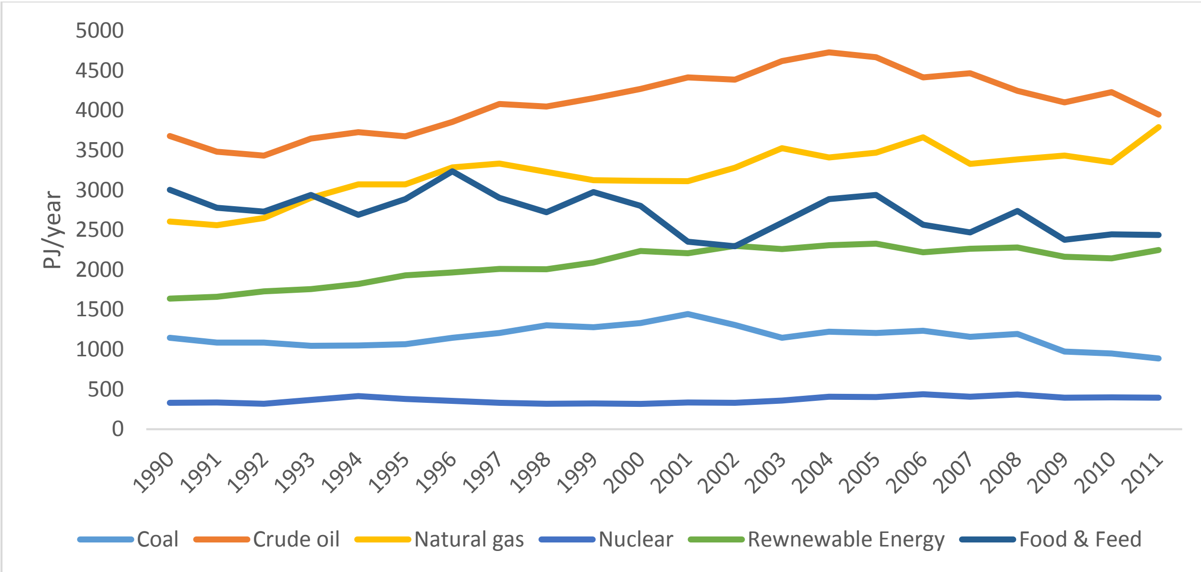



**Figure 59 DEC Energy Categories for Canada from 1990-2011**

Average Domestic Energy Consumption of US have been 9 times higher than that of Canada for 1990-2005. Both US and Canada experienced similar percentage increase in their DEC from 1990-2005 i.e. 15% and 20% respectively. DEC/capita for both countries had also been constant and similar i.e. 429 GJ/capita for US and 440 GJ/capita for Canada from 1990-2005

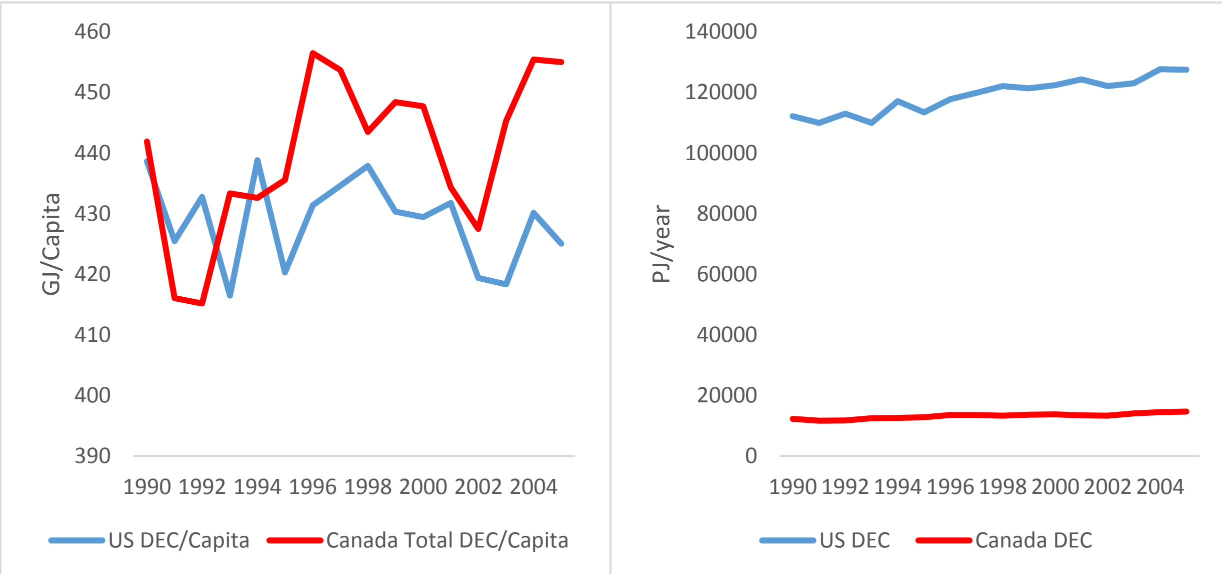



**Figure 60.1** **Figure 60.2**

**Figure 60 Domestic Energy Consumption Per Capita (60.1) and Absolute (60.2) for Canada and US over time series 1990-2005**

### 4.3.5 DE to DEC ratio

DE to DEC indicator shows the dependency of the physical economy to the domestically extracted energy. Average DE/DEC for Canada has been 1.54 from 1990-2011, which shows self-dependence of Canada for energy (Wiesz et al., 2006). Canada has high physical exports as compared to imports both in technical and food & feed energy flows (except for fruits and vegetables).

### 4.3.6 Physical Trade Balance

Physical Trade balance is the difference between physical imports and physical exports of energy carriers for Canada. The physical trade balance of energy for Canada has been negative since 1990 with an average per annum value of -7190 PJ, showing Canada as a net exporter of Energy (Figure 61).

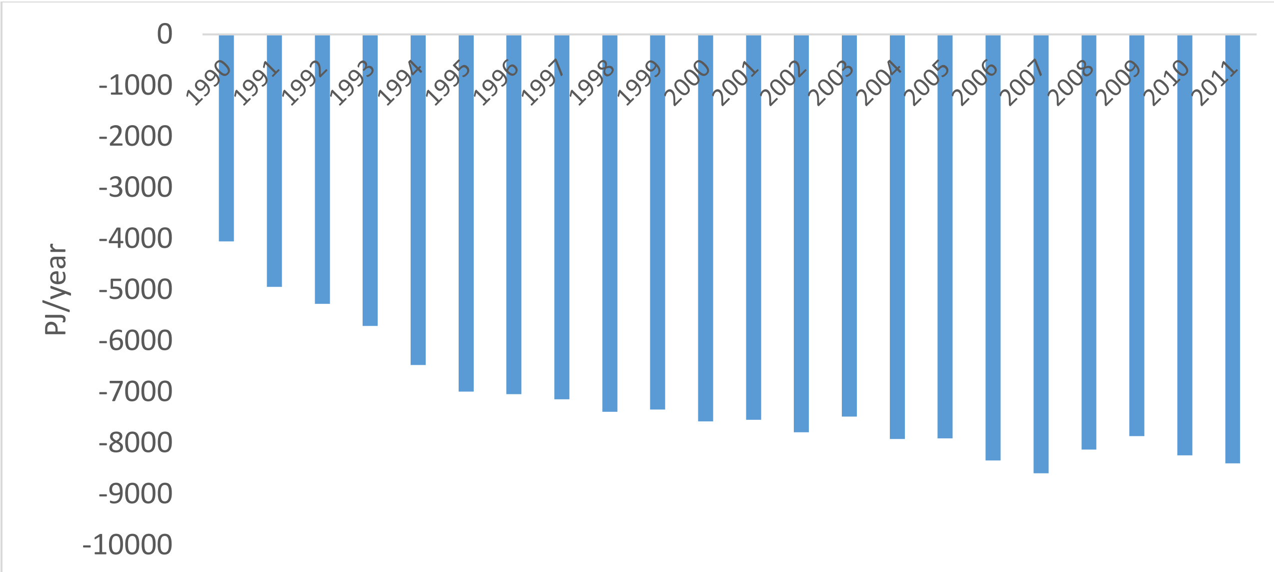



**Figure 61 Physical Trade Balance of Energy for Canada from 1990-2011**

Exports form on average per annum 76% of the total energy trade of Canada from 1990-2011, with natural gas and crude oil forming 43% and 23% on average per annum of total energy trade since 1990. Even though physical energy imports increased from 2223 PJ to 4380 PJ for the period of this study, the share of imports in the total trade went as high as 25% for these 22 years. Similar pattern is observed in the total energy exports and total energy trade, showing Canada's energy trade to be export dominant (Figure 62).

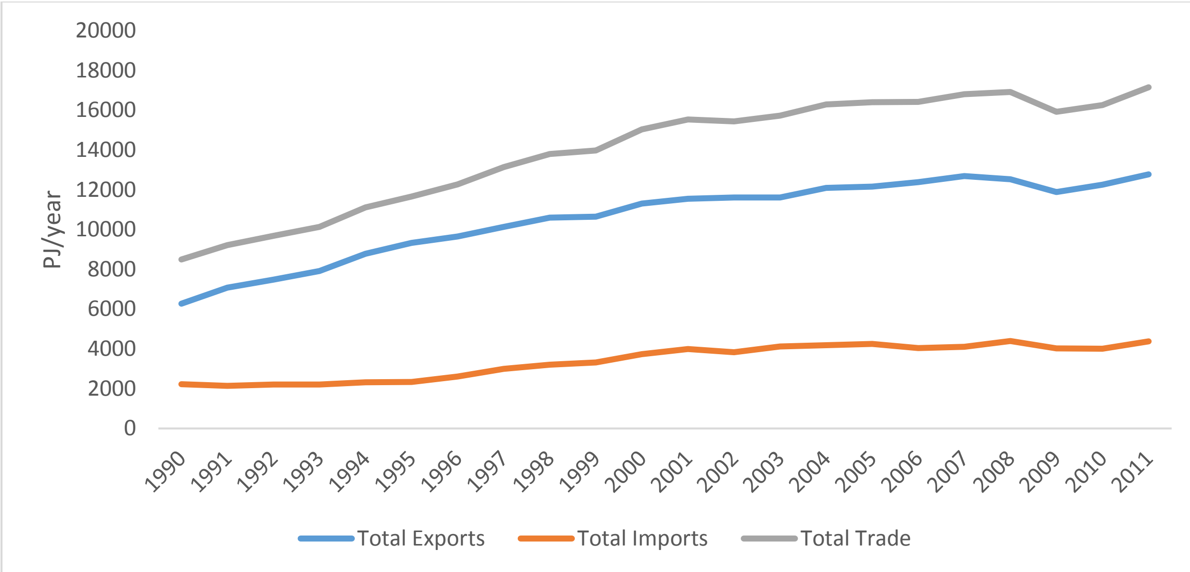



**Figure 62 Total Trade, Total Exports and Total Imports of Energy for Canada from 1990-2011**

Physical Trade Balance of Energy for US form 1990-2005 has been positive for entire period with an average value of 21818 PJ per annum, whereas that of Canada is negative with an average value of 6786 PJ per annum (Figure 63). The total trade energy flow of US has been 36723 PJ on average per annum, with share of exports decreasing from 27% to 17%, showing US energy trade relies more on imports. Whereas Canada's energy trade has leaned more towards exports with an average share of 76% per annum from 1990-2005 of the total energy trade.

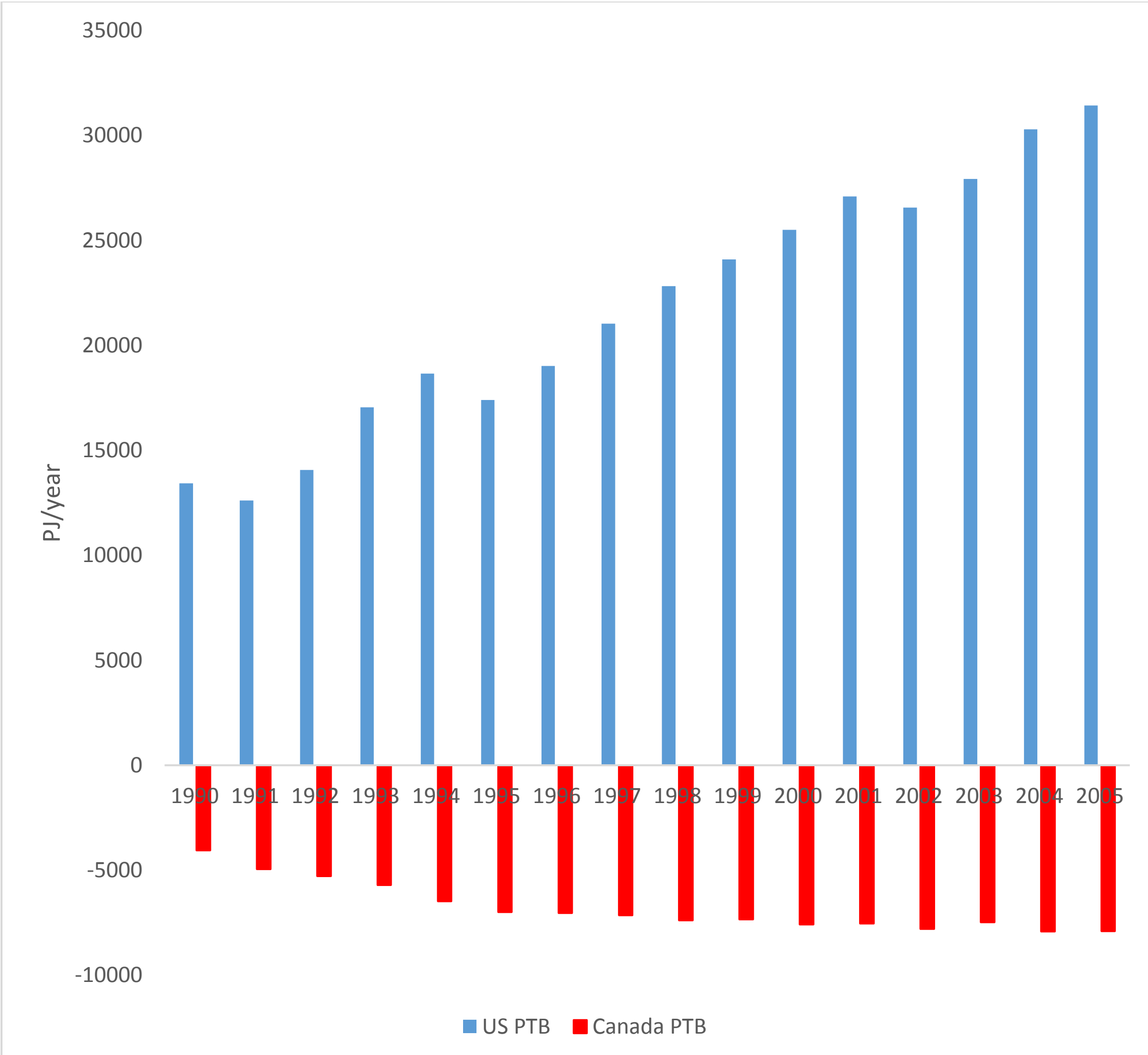



**Figure 63 Physical Trade Balance Energy for Canada and US over time series 1990-2005**

### 4.3.7 Sankey Representation

To analyze how Canada's societal energy flow changed over time, in this study 3 points in time are analyzed, 1990, 2000 and 2011. With the help of Sankey diagrams, a visual representation of Canada's system energy flow is compared after each decade (Figure 64). Looking at all these three figures only Domestic Extraction and Exports have gone through noticeable change as part of the whole metabolism of the system.

Furthermore, the Sankey representation points out towards more domestic extraction of non-renewable energy to provide for increasing exports. Also, negligible change has been seen in the DE and DEC of renewable energy in the energetic metabolism of Canada which shows huge reliance of Canada on fossil fuels. Looking at the overall energetic metabolism it can be concluded that Canada has transitioned towards a technical energy based society as most of the energy required for building stocks and carrying out flows for getting work done is coming from non-renewable energy.

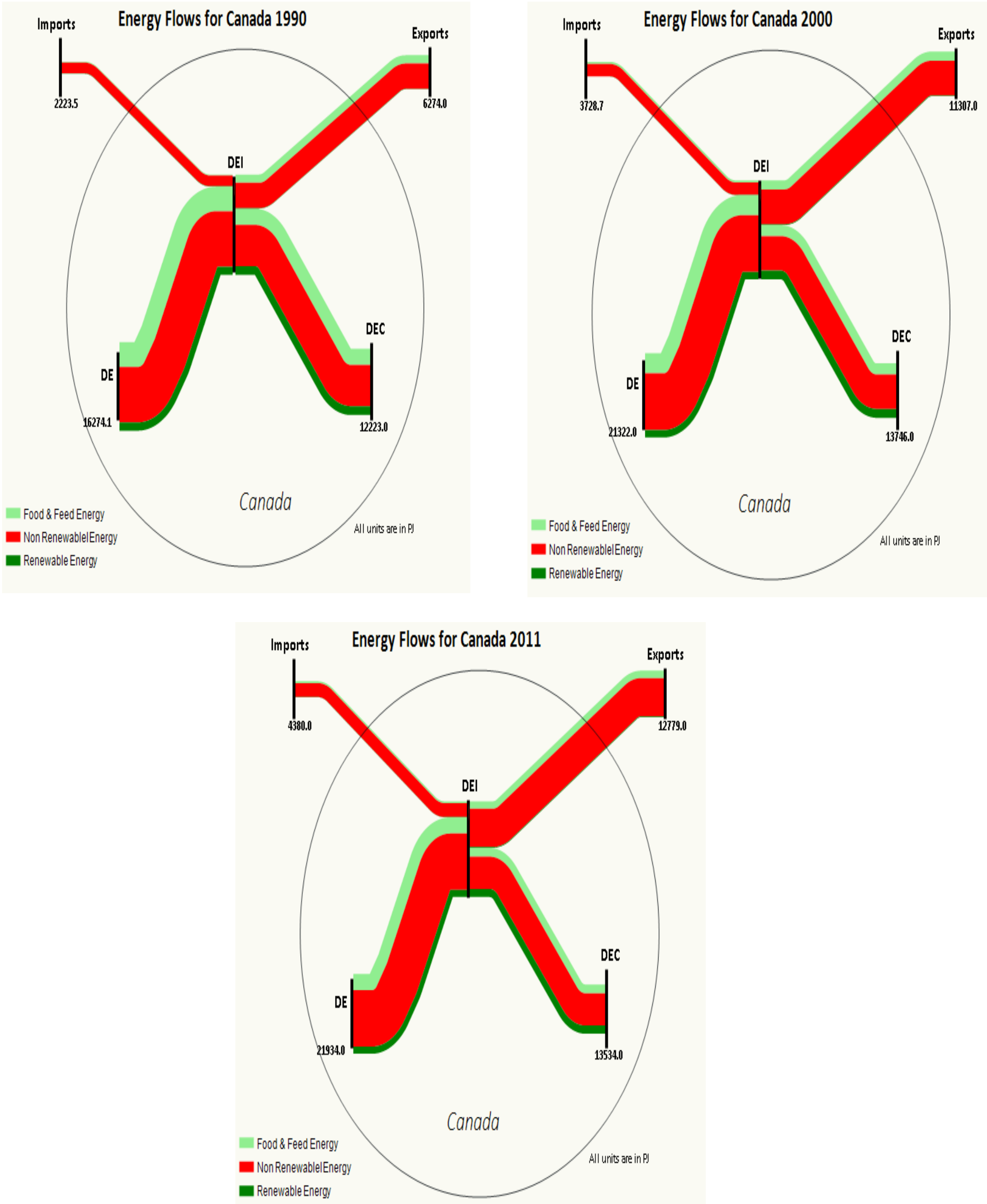



**Figure 64 Energy Metabolic Profile for Canada represented in Sankey Diagram for 1990, 2000 and 2011**

# Chapter 5 Discussion & Conclusion

This study presents a novel analysis of socio-economic metabolism of Canada for biomass and energy from 1990-2011. It contains data collection and representation of domestic extraction, import, exports and consumption of biomass & energy using MFA (Eurostat, 2013) and EFA (Haberl , 2001a) methodology, hence providing an aerial as well as micro view of components of these flows. The following discussion addresses the main research questions and the key findings from the results.

## 5.1 Metabolism of Canada

One of the aims of this study was to understand the metabolism of Canada with respect to production, consumption and trade of biomass and energy from 1990 to 2011. The metabolic profile of Canada depicts an industrial society as Canada shows similar pattern of biomass and energy production and consumption to that of USA and EU-15.

Average DE/capita of biomass for Canada is twice than that of US (Gierlinger & Krausmann, 2012) and 2.5 times to EU-15 average (Weisz et al., 2006). DMC/capita of biomass for Canada has averaged 9.6 ton/capita/year which is approximately twice that of USA (Gierlinger & Krausmann, 2012) and EU-15 (Weisz et al., 2006) and 5 times higher than developing and densely populated countries such as India and China (Singh et al., 2012). Average population density of Canada for the time period of study is 3.4 cap/km$^2$, lower than average EU-15 i.e. 116.2 cap/km$^2$ but similar to countries with high DE/capita and DMC /capita as compared to EU average such as Finland , Sweden and Ireland which too have low population density (Wiesz et al., 2006).

Animal feed contains the largest share in Canada's DMC. This is consistent with countries having high number of livestock head resulting in production of animal feed and animal grazing. Ireland and Denmark wich are part of EU-15, also have high share of animal feed because of the high number of livestock (Weisz et al 2006). Nonetheless, the feed efficiency of livestock has been improving as well as the conversion of animal feed to secondary products such as meat, dairy, eggs etc. The livestock conversion efficiency of Canada has been on average 9%, higher than World average (3.2%), Western Europe (7.2%) and similar to Eastern Europe (9.2%) (Krausmann et al., 2008).

Other than animal feed, primary crops and forestry products have also has high share in both DE and DMC for Canada, together contributing to 47% of DE and 33% of DMC. The crop yields of Canada though are less than average EU-15 (Wiesz et al., 2006), likely because of climate differences, but have been improving in the past decade (Figure 14). Although fertilizer usage has increased but it is still less than countries like Sweden and Finland which have similar crop yields to that of Canada (FAO, 2017). Thus, Canada's biomass profile resonates with an industrial society with efficiency gains in livestock conversion and yields as compared to other industrialised countries with similar DE/capita and DMC/capita. DE/DMC of Canada is greater than 1 which indicates Canada's self sufficiency for biomass. However, Canada still needs to imports fruit and vegetables which form 40% of the total imports and are increasing by each year. A drop in canadian dollar value can increase the cost of fruits and vegetables (mostly imports). Areas like Nunavut where prices of fruits and vegetables are already higher than Canadian average (Nunavut Bureau of Statistics, 2016) become more vulnerable with price changes and this can impact daily intake of fresh fruits and vegetables for communities located in such places.

Domestic Energy Consumption for Canada showed similar growth rates to the USA growing at 0.05-0.06% for DEC and similar average per capita value of 445GJ/capita/year, however it is twice as high as that of EU-15 for the same period (Haberl et al., 2006). At the same time the share of non-renewable energy in DEC of Canada has been increasing, the renewable energy consumption increasing slightly and average food & feed DEC decreasing, showing a pattern of industrialised society where societies shift from solar based biomass to non-renewable energy sources (Haberl et al., 2006).

DE of energy for Canada provides for 54% of the exports but Canada imports 29% of the energy locally consumed (due to refinery economics (NRCAN ,201)). This situation is particularly unique as the energy profile of Canada is similar to that of the USA and EU-15 with respect to DEC and Imports (Haberl et al., 2006) and similar to the Russian Federation with respect to Exports and PTB (Krausmann et al ., 2016). Canada meets its high demand of DEC from DE and Imports, but Exports of energy have been increasing contributing towards 25% of the total Canadian exports. Energy sectors contributed to 10% of the GDP for Canada in 2011 (NRCAN, 2013) and majorly consist of non-renewable fossil fuels.

Furthermore, Canada has high share of renewable energy consumption in DEC compared to the USA and the EU-15 which even though have a decreasing share of fossil fuels but are relying more on nuclear energy as a clean fuel but is still a non-renewable resource (Haberl et al., 2006). However the share of non-renewable fossil fuel in Canada’s DEC is increasing by each year and keeping in view Canada’s commitment to reduce its GHG emissions to 523 Mt by 2030, a sustainability transition is required in the energy sector of Canada.

## 5.2 Sustainability Transition in Socio-Economic Metabolism of Canada

A sustainability transition is defined as a long-term transformation process through which a socio-economic system turns to sustainable means of production and consumption of materials (Markard, Raven, & Truffer, 2012)   It can happen due to demographic, political, economic and social variables (Fischer-Kowalski , 2011). Though it is beyond the scope of this study to analyze the factors behind transitions happening in the socio-economic system, but this study analyzes the metabolic profile of Canada and links it to sustainability problems requiring a sustainability transition.

Canada has committed itself to support the implementation of global goals for sustainable development. Keeping this study in perspective, three major global goals can be discussed here. These goals are i) renewable energy, ii) sustainable agriculture and iii) climate action. Canada has high share of fossil fuel energy in DE and DEC, which contributes towards high GHG emissions and causes an adverse effect on Canada’s commitment to reduce GHG emissions. This also affects Canada’s role in implementing sustainable development goal of renewable energy and climate action, which therefore require policy and technological intervention. Furthermore, the livestock conversion efficiency and high uptake of meat in daily diets for Canada asks for a sustainability transition in the biomass sector.

### 5.2.1 Transition towards Low Carbon Economy

A transition to low carbon economy requires different policy and technological interventions in various economic and social sectors (Potvin et al., 2017). Based on this study, the focus is only on GHG emissions from oil & gas, transportation and buildings sector ( top three economic sectors as per GHG emisisons in 2015 (Government of Canada, 2017)) and the possible transition of these sectors towards low carbon economy.

Oil & gas sector forms the largest source of GHG emissions for Canada (Government of Canada, 2017). The major emisions from this sector have been from increase in crude oil production mainly from oil sands. This increase in production has been due to high exports of crude oil and natural gas from Canada which form 25% of the total exports from Canada. The exports of fossils fuels have been increasing by 10% every year from 1990-2011 twice the rate of other trade commodities which grew at 5% (Statcan, 2012). Given the considerable contribution of carbon intensive oil & gas sector towards GDP of Canada, a transition towards low carbon economy can result in unemployment and reduction in export revenue. To decouple the oil production from economic growth and avoid negative impacts, policy intervention is required. This can incorporate multi-skill training of workers from oil & gas. For example, a transition to renewable energy infrastructure will required skilled workers and oil & gas manpower can be trained in renewable technologies (Potvin et al., 2017). Other opportunities include transitioning to green building construction, financial services, tourism and advanced technologies such as nano-technology to provide for the loss of GDP from fossil fuels (Alberta Government, 2016)

Transportation is the second largest sector responsible for GHG emissions for Canada. Major components for GHG emissions from this sector are passenger cars, passenger light trucks and freight vehicles (Government of Canada, 2017). A shift towards low carbon transportation can be brought about by the usage of electric and plug-in hybrid vehicles (McKinsey, 2012) and decarbonising the local transit by using electric trains and autonomous cars (Schoitsch, 2016). To move towards a low carbon freight transportation, actions such as moving to hybrid-electric trucks for long-range distances, reserved truck lanes to reduce congestion for freight trucks and right sized vehicles for deliveries are required (Potvin et al.,2017). Use of electric train for freight within the country can be another prospect for reducing freight transportation emissions, as trains are shown to be more energy efficient than trucks on a life cycle basis (Nahlik et al., 2015).

The third largest sector contributing towards GHG emissions is buildings. This sector include residential and commercial buildings which rely on natural gas for heating and electricity for power needs. While electricity in Canada is being generated by 80% non-carbon fuel (Government of Canada, 2017), natural gas is mainly used for heating purposes. To reduce GHG emissions in this sector, energy efficiency and innovative renewable energy solutions are required. This can include reusing waste heat, developing carbon neutral building codes and renovating current buildings according to it (Sandberg et al., 2016), and replacing natural gas (for heating purposes) with renewable fuels such as solar heaters, waste heat from sewage, geo-thermal, etc. (Pond et al., 2011). A new concept of Net-Zero Energy housing is emerging in Canada, where a net zero energy house is built with reduced energy requirement, on-site renewable energy systems and is operated efficiently (CMHC, 2018).

All these technological and policy changes discussed above can pave the way towards a low carbon economy for Canada and aid to achieve its goal of shifting to renewable energy and reduction in GHG emissions, while maintaining jobs and GDP growth.

### 5.2.2 Transition to Sustainable Agriculture

From the biomass material flows, the share of animal feed & animal products dominates the overall biomass metabolism of Canada (35% of DE and 47% of DMC). Average yearly meat and dairy production in Canada is 12.2 Mt, of which 2.2 Mt is exported, and 1.17 Mt is imported.

The Canadian food balance data of 2011 also suggests a high share of animal products in the diet, with 34% in weight and 25% in nutritional energy (FAOSTAT 2017). From a sustainability perspective this is problematic, since the conversion of feed and fodder to secondary animal products such as meat, poultry and milk is highly inefficient (Krausmann et al., 2008). According to calculations for Canada during the study period, this conversion efficiency from feed to animal and dairy products is on an average 9%. However, the trends in the consumption of animal products per capita show a modest decline, from 35% to 34% in weight and 28% to 25% in energy supply during the study period (FAO, 2017). This may be due to a combination of several factors, from health to increasing costs of animal and dairy products.

Along with decreasing the efficiency of the biomass food system, livestock system accounts for 60% of the total direct GHG emissions by the agriculture sector, which contribute to 6% of total GHG emissions in Canada (Frenette, Bahn & Vaillancourt, 2017). To improve the material intensity of food supply (Haas et al., 2005) and reduce GHG emissions from the agricultural sector, it is important to change dietary patterns and transition towards a less share of animal products in daily food uptake. Although direct animal GHG emissions may only be 3.6% of total Canadian emissions, on a life cycle basis, the energy used to process, transport, store and prepare animal products was shown to contribute up to 65% of the GHG emissions in Ontario dietary patterns (Veeramani et al., 2017). However, Canada's climate is cold and much of its land is not arable, and is most suitable for grazing animals. Nonetheless, there could be a reduction in some types of animals (e.g. pigs or cattle that are not grass-fed) based on optimizing resource use (land, water, etc.) and adapting to local conditions and ecosystems. However, this sort of transition from animal food to plant food requires further research and understanding of tradeoffs associated with it.

## 5.3 Limitations

The data for time series from 1990-2011 was selected for both biomass and energy data collection as IEA (2017) database starts from the year 1990. To be consistent with the biomass and energy flow analysis, same time series was selected for each. The entire data was collected in 2016 and 2011 was selected as cut-off year due to availability of data from IEA (2017).

The data contain calculations and assumptions for biomass category of animal grazing, crop residues and animal weight. Furthermore, conversion factors have been used for timber & fuel wood and biomass conversion from weight to energy. These factors have been taken from MEFA literature and guidelines which can be average values and hence may not represent actual scenario in Canada. These calculations and assumptions can affect data validity which can impact the interpretation of the main results such as livestock conversion efficiency which includes animal feed of grazing and data for available crop residues which can be used for biofuel calculations in future research. Furthermore, the conclusions derived in this study from the results are from data cut-off year of 2011 and may not reflect current scenario of Canada.

## 5.4 Conclusion

In conclusion, this study provided an analysis of biomass and energy flows of Canada from 1990-2011 consistent with MFA and EFA methodologies. The aim of this study was to understand socio-economic metabolism of Canada with respect to biomass and energy flows, as well as to provide an insight of potential sustainability transition in biomass and energy sector. Summarizing the socio-economic metabolism analysis of this study, Canada is a net exporter of both biomass and energy and holds a strong position in the world for the supply of these materials. Viewing the extraction and domestic consumption of the flows, Canada's metabolism depicts an industrial metabolism. Canada is a self-sufficient country for biomass (except for fruit and vegetables) and energy flows. Also reflected in this study is the fact that the Canadian economy is highly dependent on the exports of biomass and energy resources and draws a large revenue towards its total trade merchandise as resource is extracted for both domestic and trade purposes.

Also, this study supports the feasibility of inclusion of biomass in the EFA analysis as in previous EFA studies (Haberl et al., 2006) and draws data from MFA accounts and converts them into GCV. Overall this research endeavors to provide insights into the current biomass and energy structure of Canada for developing policies on a national and global scale with a potential of sustainability transition in energy and biomass sector. It also inputs towards a unique way of viewing socio-economic system of Canada with respect to natural resources.

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# Appendix I

## Biomass Flows Table

(All values are in Tons)

| Biomass Flows | | | | | |
|---|---|---|---|---|---|
| **Year** | **DE** | **Import** | **Export** | **DMC** | **PTB** |
| **1990** | 379521717.4 | 14470409.59 | 83363084.75 | 310629042.2 | -68892675.15 |
| **1991** | 363888481 | 14776884.09 | 90749096.87 | 287916268.2 | -75972212.78 |
| **1992** | 358495231 | 18490776.86 | 93158646.5 | 283827361.4 | -74667869.65 |
| **1993** | 376912402 | 19439959.59 | 93069103.44 | 303283258.1 | -73629143.85 |
| **1994** | 386530854 | 21546789.48 | 104191181.3 | 303886462.1 | -82644391.86 |
| **1995** | 381916245.5 | 23739788.54 | 103180216.4 | 302475817.6 | -79440427.9 |
| **1996** | 400647907 | 23998637.11 | 104012307.8 | 320634236.3 | -80013670.71 |
| **1997** | 369298740.5 | 27839904.4 | 109688608.6 | 287450036.3 | -81848704.22 |
| **1998** | 372135376.5 | 29668430.32 | 115213215.6 | 286590591.2 | -85544785.29 |
| **1999** | 399931670 | 30051483.92 | 117944580.5 | 312038573.4 | -87893096.57 |
| **2000** | 392713135.5 | 36425399.33 | 125396385.1 | 303742149.7 | -88970985.75 |
| **2001** | 351476100 | 39686820.5 | 123655845 | 267507075.5 | -83969024.47 |
| **2002** | 338060105 | 38405682.34 | 118216271.3 | 258249516.1 | -79810588.92 |
| **2003** | 371364952 | 38357170.79 | 119273595.2 | 290448527.6 | -80916424.43 |
| **2004** | 410993117 | 37968309.7 | 130168708.2 | 318792718.5 | -92200398.52 |
| **2005** | 402646664 | 39109225.44 | 130455132.2 | 311300757.3 | -91345906.73 |
| **2006** | 388482300 | 36404338.03 | 133011946.1 | 291874691.9 | -96607608.12 |
| **2007** | 374479791 | 38091576.85 | 122639445.5 | 289931922.4 | -84547868.63 |
| **2008** | 382382450 | 40346106.86 | 113673243.8 | 309055313.1 | -73327136.93 |
| **2009** | 358510817.5 | 35825461.22 | 105672583.9 | 288663694.8 | -69847122.7 |
| **2010** | 364709656.7 | 36748457.13 | 110989546.9 | 290468566.9 | -74241089.78 |
| **2011** | 369560154.9 | 35826908.83 | 113026848.1 | 292360215.7 | -77199939.25 |

## Crop Yields

(All values are in tons/ha)

| | Cereals,Total | Fibre Crops Primary | Fruits | Oilcrops Primary | Pulses,Total | Roots and Tubers,Total | Vegetables | Sugar Crops |
|---|---|---|---|---|---|---|---|---|
| **1990** | 2.6363 | 1.2115 | 10.7487 | 0.4782 | 1.8687 | 25.0994 | 19.5903 | 39.0747 |
| **1991** | 2.5807 | 1.2097 | 10.0611 | 0.4937 | 1.6778 | 23.8293 | 17.5733 | 43.6181 |
| **1992** | 2.4607 | 1.2016 | 10.5626 | 0.4717 | 1.6617 | 29.1406 | 17.8714 | 34.2321 |
| **1993** | 2.6472 | 1.2036 | 8.9824 | 0.4907 | 1.6548 | 26.5498 | 20.1781 | 35.1707 |
| **1994** | 2.5949 | 1.2277 | 10.3332 | 0.4735 | 1.7927 | 27.6644 | 21.3592 | 42.7961 |
| **1995** | 2.6999 | 1.2011 | 11.3409 | 0.4627 | 1.7076 | 26.5973 | 20.3454 | 41.5749 |
| **1996** | 2.8442 | 1.2033 | 10.1639 | 0.5276 | 1.884 | 27.7298 | 20.2055 | 44.2912 |
| **1997** | 2.5842 | 1.1992 | 10.1349 | 0.4779 | 1.8225 | 27.4227 | 20.3572 | 44.8446 |
| **1998** | 2.7826 | 1.2008 | 10.2277 | 0.5131 | 1.9312 | 27.6833 | 21.5626 | 48.3516 |
| **1999** | 3.0877 | 1.2062 | 12.7007 | 0.5678 | 2.1374 | 27.2508 | 21.5901 | 42.7529 |
| **2000** | 2.8057 | 1.2043 | 11.399 | 0.5287 | 1.8861 | 28.6821 | 20.9654 | 49.4578 |
| **2001** | 2.4468 | 1.201 | 10.3873 | 0.441 | 1.2986 | 25.3251 | 20.5966 | 46.5214 |
| **2002** | 2.3754 | 1.2007 | 9.3261 | 0.4429 | 1.2907 | 27.5315 | 21.2329 | 34.1287 |
| **2003** | 2.7596 | 1.2014 | 9.1386 | 0.4906 | 1.5123 | 29.2024 | 21.2209 | 56.2314 |
| **2004** | 3.1419 | 1.203 | 9.6022 | 0.5462 | 2.0219 | 30.4861 | 23.1029 | 52.3873 |
| **2005** | 3.2159 | 1.2017 | 9.3065 | 0.6297 | 1.9984 | 28.3767 | 24.1369 | 45.3582 |
| **2006** | 3.0463 | 1.2013 | 9.2897 | 0.6044 | 1.7949 | 32.1821 | 25.942 | 58.06 |
| **2007** | 2.9649 | 1.2025 | 9.7733 | 0.5368 | 1.7779 | 31.4574 | 24.7489 | 55.2174 |
| **2008** | 3.3872 | 1.1957 | 9.777 | 0.6777 | 2.0192 | 31.2066 | 25.4734 | 49.9565 |
| **2009** | 3.2975 | 1.1875 | 10.0698 | 0.6789 | 1.9919 | 31.3126 | 24.5191 | 60.3394 |
| **2010** | 3.4832 | 1.1875 | 9.0957 | 0.6591 | 1.826 | 31.6055 | 24.5663 | 49.5575 |
| **2011** | 3.524 | 1.1875 | 9.4027 | 0.6711 | 2.059 | 29.5863 | 24.8223 | 64.0496 |

## Area harvested

(All values are in hectares)

| | Cereals,Total | Fibre Crops Primary | Fruit | Oilcrops Primary | Pulses,Total | Roots and Tubers,Total | Vegetables Primary |
|---|---|---|---|---|---|---|---|
| **1990** | 21547874 | 43500 | 71895 | 4003958 | 313900 | 119700 | 110518 |
| **1991** | 20868958 | 36000 | 72501 | 4434840 | 534040 | 118735 | 105155 |
| **1992** | 20176400 | 30500 | 75659 | 4083634 | 596500 | 123793 | 106116 |
| **1993** | 19448200 | 27500 | 77662 | 5594100 | 879800 | 124890 | 99769 |
| **1994** | 17965100 | 32500 | 77146 | 7714600 | 1158520 | 132900 | 105084 |
| **1995** | 18276400 | 44000 | 76367 | 7264500 | 1227770 | 144150 | 109851 |
| **1996** | 20566100 | 61000 | 74860 | 5151200 | 911880 | 147300 | 114388 |
| **1997** | 19177100 | 59000 | 72604 | 7009900 | 1277300 | 152100 | 112340 |
| **1998** | 18325300 | 60500 | 71324 | 7615900 | 1587800 | 156376 | 110200 |
| **1999** | 17513800 | 56500 | 72326 | 7631200 | 1615900 | 156619 | 111234 |
| **2000** | 18209500 | 46000 | 72218 | 6792300 | 2355500 | 159240 | 109397 |
| **2001** | 17733700 | 49000 | 72229 | 5742800 | 2591700 | 166650 | 112903 |
| **2002** | 15174800 | 29150 | 72822 | 5637400 | 1697400 | 170900 | 112952 |
| **2003** | 17824900 | 28300 | 74696 | 6903100 | 1877600 | 180890 | 116177 |
| **2004** | 16161700 | 26600 | 75183 | 6902900 | 2125500 | 171712 | 110194 |
| **2005** | 15846800 | 35700 | 74558 | 7337468 | 2296600 | 156256 | 102294 |
| **2006** | 15946100 | 54150 | 79111 | 7435910 | 2097200 | 158198 | 97904 |
| **2007** | 16226000 | 32100 | 74963 | 8293335 | 2351700 | 158927 | 104692 |
| **2008** | 16541300 | 23000 | 79352 | 8575259 | 2450300 | 151393 | 94991 |
| **2009** | 15027100 | 24000 | 79220 | 8797381 | 2605000 | 146303 | 97383 |
| **2010** | 13147100 | 24000 | 77198 | 8921701 | 2928500 | 139905 | 95258 |
| **2011** | 13429000 | 24000 | 82229 | 9435020 | 2099900 | 140882 | 92998 |

# Livestock

(All values are in heads)

| | Cattle | Sheep | Goats | Pigs | Horses | Mules | Chickens | Ducks | Geese and guinea fowls | Turkeys |
|---|---|---|---|---|---|---|---|---|---|---|
| **1990** | 11220400 | 595000 | 27300 | 10392400 | 415000 | 4000 | 111000 | 720 | 460 | 4300 |
| **1991** | 11288800 | 628300 | 27500 | 10172000 | 419000 | 4000 | 112000 | 820 | 280 | 5200 |
| **1992** | 11869000 | 647900 | 27500 | 10596300 | 350000 | 4000 | 108000 | 900 | 215 | 5800 |
| **1993** | 11860000 | 632500 | 27650 | 10743700 | 370000 | 4000 | 115000 | 1000 | 230 | 5600 |
| **1994** | 12012000 | 639300 | 27800 | 10533800 | 350000 | 4000 | 132000 | 1100 | 250 | 5700 |
| **1995** | 12708700 | 617300 | 28000 | 11290500 | 380000 | 4000 | 136000 | 1200 | 280 | 5900 |
| **1996** | 13401700 | 643000 | 28500 | 11588000 | 376000 | 4000 | 142000 | 1250 | 300 | 5700 |
| **1997** | 13411600 | 627800 | 28500 | 11479500 | 400000 | 4000 | 138000 | 1150 | 300 | 5400 |
| **1998** | 13359900 | 662000 | 29000 | 11985300 | 380000 | 4000 | 140000 | 1140 | 300 | 5700 |
| **1999** | 13211300 | 717000 | 30000 | 12429400 | 380000 | 4000 | 155000 | 1140 | 300 | 5200 |
| **2000** | 13201300 | 793000 | 30000 | 12904400 | 385000 | 4000 | 158000 | 1150 | 300 | 5400 |
| **2001** | 13608200 | 947800 | 30000 | 13575500 | 470000 | 4000 | 158000 | 1150 | 300 | 6470 |
| **2002** | 13751500 | 993600 | 30000 | 14375000 | 385000 | 4000 | 160000 | 1150 | 300 | 5900 |
| **2003** | 13466000 | 975300 | 30000 | 14745000 | 385000 | 4000 | 160000 | 1150 | 300 | 5600 |
| **2004** | 14555000 | 994200 | 30000 | 14725000 | 385000 | 4000 | 160000 | 1150 | 300 | 5520 |
| **2005** | 14925000 | 977600 | 30000 | 14810000 | 385000 | 4000 | 160000 | 1150 | 300 | 5600 |
| **2006** | 14655000 | 893800 | 30000 | 14980000 | 385000 | 4000 | 160000 | 1150 | 300 | 5600 |
| **2007** | 14155000 | 886200 | 30000 | 14080000 | 385000 | 4000 | 165000 | 1150 | 300 | 5600 |
| **2008** | 13895000 | 849500 | 30000 | 12700000 | 390000 | 4000 | 165000 | 1200 | 300 | 5880 |
| **2009** | 13180000 | 843600 | 30000 | 12465000 | 390000 | 4000 | 165000 | 1250 | 310 | 5600 |
| **2010** | 13013000 | 855300 | 30000 | 12690000 | 400000 | 4000 | 165000 | 1300 | 320 | 5400 |
| **2011** | 12155000 | 879300 | 30000 | 12785000 | 405000 | 4000 | 164600 | 1350 | 330 | 5500 |

# Biomass DE Category Wise

(All values are in tons)

| Biomass / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 56806235 | 53857200 | 49647550 | 51483100 | 46617100 | 49344200 | 58494100 | 49557300 | 50992500 | 54077500 | 51090400 | 43391400 | 36046900 | 49189000 | 50778200 | 50962400 | 48577300 | 48108800 | 56028700 | 49552100 | 45661800 | 47297600 |
| Root & Tubers | 3004400 | 2829373 | 3607400 | 3315800 | 3676600 | 3834000 | 4084600 | 4171000 | 4329000 | 4268000 | 4567330 | 4220430 | 4705130 | 5282420 | 5234837 | 4434024 | 5091140 | 4999424 | 4724460 | 4581123 | 4421773 | 4168175 |
| Sugar Crops | 941700 | 1085000 | 775700 | 782900 | 1091300 | 1026900 | 1034200 | 635000 | 880000 | 743900 | 821000 | 544300 | 344700 | 680400 | 743900 | 607800 | 870900 | 762000 | 344700 | 657700 | 560000 | 775000 |
| Pulses | 586600 | 896000 | 991200 | 1455900 | 2070223 | 2096600 | 1718020 | 2327900 | 3066300 | 3453900 | 4442700 | 3365500 | 2190900 | 2839500 | 4297600 | 4589600 | 3764300 | 4181100 | 4947700 | 5188900 | 5347300 | 4323600 |
| Treenuts | | | | | | | | | | | | | | | | | | | | | | |
| Oil Bearing Crops | 5777000 | 6576000 | 5863000 | 8253000 | 10881000 | 10147000 | 8369000 | 10336000 | 11813000 | 12946000 | 10930000 | 7579000 | 7849000 | 10170000 | 11576000 | 13901000 | 13724000 | 13182000 | 17118000 | 17641000 | 17804000 | 18943000 |
| Vegetables | 2165082 | 1847920 | 1896440 | 2013160 | 2244510 | 2234950 | 2311280 | 2286930 | 2376196 | 2401550 | 2293552 | 2325415 | 2398293 | 2465378 | 2545795 | 2469057 | 2539824 | 2591008 | 2419744 | 2387741 | 2334618 | 2303149 |
| Fruits | 772777 | 729443 | 799155 | 697587 | 797166 | 866068 | 760866 | 735831 | 729477 | 918588 | 823210 | 750270 | 679143 | 682618 | 721925 | 693875 | 734917 | 732633 | 775827 | 797740 | 702192 | 773206 |
| Fibre Crops | 52700 | 43550 | 36650 | 33100 | 39900 | 52850 | 73400 | 70750 | 72650 | 68150 | 55400 | 58850 | 35000 | 34000 | 32000 | 42900 | 65050 | 38600 | 27500 | 28500 | 28500 | 28500 |
| Other Crops | 63057 | 78704 | 65640 | 77476 | 70140 | 74219 | 70151 | 76204 | 73178 | 70215 | 53010 | 58606 | 54550 | 46338 | 42430 | 43000 | 48525 | 44000 | 44718 | 45951 | 40120 | 33575 |
| Spices | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2000 | 8000 | 8000 | 10000 | 9000 | 8000 | 11000 | 7000 | 8000 | 8000 | 8000 |
| Straw | 47717237.4 | 45240048 | 41703942 | 43245804 | 39158364 | 41449128 | 49135044 | 41628132 | 42833700 | 45425100 | 42915936 | 36448776 | 30279396 | 41318760 | 42653688 | 42808416 | 40804932 | 40411392 | 47064108 | 41623764 | 38355912 | 39729984 |
| Other Crop residues | 6101916 | 7656006 | 6922995 | 9410629 | 12309147 | 11196369 | 9258961 | 11264386 | 13124943 | 14622157 | 12484134 | 8487830 | 8340944 | 11479105 | 13281011 | 15726587 | 15579521 | 15632471 | 19940964 | 20599504 | 21055561 | 22912737 |
| Fodder Crops | 137508600 | 1.22E+08 | 1.16E+08 | 1.24E+08 | 1.32E+08 | 1.13E+08 | 1.16E+08 | 89425900 | 93725300 | 1.07E+08 | 1.02E+08 | 87579000 | 78919800 | 96655000 | 1.1E+08 | 95653000 | 99680600 | 1.02E+08 | 1.04E+08 | 1.08E+08 | 1.06E+08 | 1.06E+08 |
| Grazed Biomass | 20032729 | 23944549 | 27800507 | 25965182 | 24651140 | 32312686 | 34892581 | 41154064 | 39854405 | 36156378 | 37379280 | 42892535 | 45280697 | 39819025 | 41533351 | 46621145 | 44417759 | 41586799 | 40016509 | 35824687 | 35587141 | 31752388 |
| Timber Industrial Roundwood | 91824920 | 90453572 | 96484036 | 1.01E+08 | 1.06E+08 | 1.09E+08 | 1.1E+08 | 1.11E+08 | 1.05E+08 | 1.15E+08 | 1.2E+08 | 1.1E+08 | 1.18E+08 | 1.07E+08 | 1.24E+08 | 1.21E+08 | 1.09E+08 | 96585192 | 81729296 | 68320824 | 83426200 | 88428721 |
| Fuel Wood and Other Extraction | 4438764 | 4795516 | 4561216 | 4578948 | 4198040 | 3790644 | 3848460 | 3681700 | 2191596 | 2072312 | 2096468 | 2080672 | 2052072 | 2052116 | 2014320 | 2056472 | 2097964 | 2279772 | 2230624 | 2131184 | 2281140 | 969020.3 |
| Alcoholic Beverages | | | | | | | | | | | | | | | | | | | | | | |
| Stimulant | | | | | | | | | | | | | | | | | | | | | | |
| Fish-Seafood | 1682000 | 1510000 | 1332000 | 1185000 | 1075000 | 909000 | 964000 | 1039000 | 1085000 | 1120000 | 1118000 | 1188000 | 1229000 | 1268000 | 1311000 | 1252000 | 1243000 | 1170000 | 1095000 | 1096000 | 1079000 | 1079000 |
| Aquatic Products-Other | 46000 | 39000 | 44000 | 30000 | 38000 | 37000 | 34000 | 44000 | 37000 | 40000 | 43000 | 42000 | 48000 | 53000 | 48000 | 48000 | 52000 | 27000 | 27000 | 52000 | 47000 | 47000 |
| Textile | | | | | | | | | | | | | | | | | | | | | | |

# Biomass Import Category Wise

| Biomass \ Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 1195000 | 834000 | 1466000 | 1577000 | 1548000 | 1865000 | 1857000 | 2100000 | 2371000 | 2140000 | 2684000 | 4608000 | 5428000 | 5129000 | 3337000 | 3512000 | 3329000 | 4201000 | 4457000 | 3587000 | 3279000 | 2770000 |
| Root & Tubers | 231000 | 194000 | 304000 | 318000 | 376000 | 341000 | 342000 | 388000 | 407000 | 360000 | 402000 | 408000 | 491000 | 431000 | 371000 | 399000 | 426000 | 404000 | 446000 | 500000 | 562000 | 571000 |
| Sugar Crops | 1251000 | 1209000 | 1216000 | 1361000 | 1365000 | 1262000 | 1512000 | 1388000 | 1473000 | 1221000 | 1580000 | 1677000 | 1707000 | 1962000 | 1597000 | 1864000 | 1858000 | 1828000 | 1908000 | 1609000 | 1585000 | 1775000 |
| Pulses | 28000 | 28000 | 30000 | 31000 | 33000 | 37000 | 47000 | 53000 | 56000 | 97000 | 69000 | 72000 | 100000 | 95000 | 73000 | 139000 | 108000 | 104000 | 107000 | 119000 | 148000 | 120000 |
| Treenuts | 73000 | 78000 | 76000 | 84000 | 78000 | 64000 | 71000 | 69000 | 83000 | 83000 | 92000 | 102000 | 113000 | 118000 | 129000 | 122000 | 124000 | 147000 | 147000 | 143000 | 153000 | 162000 |
| Oil Bearing Crops | 599000 | 490000 | 497000 | 673000 | 436000 | 526000 | 679000 | 948000 | 746000 | 1064000 | 1149000 | 1571000 | 1657000 | 1568000 | 1398000 | 1255000 | 1208000 | 1214000 | 1341000 | 1408000 | 1372000 | 1227000 |
| Vegetables | 1454000 | 1544000 | 1730000 | 1843000 | 1776000 | 1813000 | 1884000 | 1982000 | 2034000 | 2125000 | 2183000 | 2289000 | 2440000 | 2404000 | 2429000 | 2422000 | 2467000 | 2532000 | 2502000 | 2547000 | 2643000 | 2813000 |
| Fruits | 2674000 | 2736000 | 2793000 | 2838000 | 3024000 | 3102000 | 3293000 | 3536000 | 3430000 | 3541000 | 3662000 | 3723000 | 3871000 | 3935000 | 3976000 | 4222000 | 4286000 | 4731000 | 4575000 | 4422000 | 4474000 | 4523000 |
| Fibre Crops | 446 | 1040 | 2633 | 507 | 656 | 467 | 445 | 560 | 444 | 591 | 470 | 1036 | 1373 | 940 | 1097 | 451 | 224 | 256 | 523 | 330 | 345 | 191 |
| Tobacco and Products | 2845 | 3777 | 10954 | 12088 | 13939 | 13503 | 17259 | 20662 | 17816 | 5363 | 8566 | 6804 | 7612 | 10523 | 8825 | 11077 | 16091 | 21881 | 25535 | 16164 | 41051 | 35928 |
| Spices | 13000 | 13000 | 14000 | 16000 | 17000 | 17000 | 19000 | 21000 | 20000 | 23000 | 23000 | 24000 | 25000 | 24000 | 27000 | 29000 | 32000 | 33000 | 35000 | 35000 | 34000 | 37000 |
| Straw | 21661 | 32946 | 37427 | 38786 | 6690 | 5799 | 13522 | 33957 | 9731 | 14534 | 33202 | 49355 | 55366 | 52422 | 61298 | 59351 | 60488 | 74378 | 77986 | 91160 | 80846 | 81343 |
| Animal Feed | 296612 | 289189 | 347335 | 336759 | 405557 | 524571 | 534684 | 564799 | 538659 | 526849 | 486393 | 644783 | 597548 | 577409 | 663419 | 701219 | 698166 | 968756 | 1343013 | 1421675 | 1777948 | 1371111 |
| Live Animals | 164715.1 | 189942.1 | 180834.1 | 165348.2 | 175834.3 | 153656.5 | 127570 | 184767.5 | 221080.2 | 232888.3 | 277425.3 | 251683.3 | 171643.6 | 121505.8 | 141767.6 | 148934.7 | 139060.5 | 181979.4 | 211615.2 | 200015.2 | 215676.9 | 236407.6 |
| Meat | 282000 | 310000 | 320000 | 385000 | 413000 | 384000 | 387000 | 439000 | 453000 | 484000 | 512000 | 579000 | 607000 | 551000 | 415000 | 483000 | 539000 | 654000 | 678000 | 673000 | 678000 | 741000 |
| Animal Fat | 44000 | 53000 | 63000 | 74000 | 91000 | 114000 | 130000 | 111000 | 136000 | 151000 | 129000 | 184000 | 157000 | 155000 | 157000 | 144000 | 139000 | 140000 | 141000 | 164000 | 189000 | 182000 |
| Eggs | 16000 | 18000 | 18000 | 21000 | 23000 | 26000 | 28000 | 38000 | 49000 | 35000 | 31000 | 46000 | 33000 | 26000 | 46000 | 32000 | 27000 | 26000 | 32000 | 38000 | 35000 | 32000 |
| Milk | 331000 | 320000 | 339000 | 370000 | 412000 | 340000 | 349000 | 346000 | 339000 | 397000 | 662000 | 639000 | 712000 | 814000 | 732000 | 657000 | 607000 | 661000 | 821000 | 477000 | 516000 | 537000 |
| Timber Industrial Roundwood | 4841081 | 5500300 | 7937226 | 8068820 | 9947094 | 11797577 | 11086190 | 13866554 | 15469349 | 15624246 | 20342476 | 20563930 | 18131646 | 18221141 | 20054465 | 20438911 | 17778469 | 17099630 | 18284330 | 15247308 | 15510981 | 14749642 |
| Fuel Wood and Other Extraction | 8600 | 9300 | 64198.28 | 63126.26 | 81678.26 | 88042.03 | 83284.06 | 113382.6 | 94243.48 | 109254.3 | 65063.07 | 88953.1 | 96686.23 | 77582.61 | 208878.3 | 337923.9 | 337804.3 | 429223.2 | 598394.9 | 731123.2 | 640469.6 | 561308.6 |
| Alcoholic Beverages | 260000 | 247000 | 240000 | 244000 | 260000 | 281000 | 323000 | 372000 | 417000 | 483000 | 512000 | 576000 | 552000 | 683000 | 688000 | 752000 | 744000 | 1231000 | 1286000 | 1046000 | 1300000 | 1747000 |
| Stimulant | 230000 | 242000 | 265000 | 279000 | 299000 | 289000 | 310000 | 329000 | 382000 | 380000 | 390000 | 408000 | 396000 | 416000 | 484000 | 446000 | 501000 | 502000 | 492000 | 485000 | 558000 | 598000 |
| Fish-Seafood | 389000 | 368000 | 471000 | 572000 | 695000 | 619000 | 819000 | 850000 | 808000 | 873000 | 1033000 | 1080000 | 973000 | 898000 | 883000 | 868000 | 928000 | 867000 | 815000 | 844000 | 931000 | 931000 |
| Aquatic Products-Other | 2000 | 2000 | 2000 | 0 | 0 | 1000 | 1000 | 1000 | 2000 | 1000 | 1000 | 1000 | 1000 | 1000 | 2000 | 2000 | 3000 | 2000 | 3000 | 5000 | 4000 | 4000 |
| Textile | 62449 | 64390 | 66169 | 68525 | 69341 | 75173 | 84683 | 84222 | 111108 | 79758 | 97804 | 93276 | 80808 | 85647 | 84560 | 63358 | 48035 | 38473 | 18710 | 15686 | 20140 | 20978 |

# Biomass Export Category Wise

(All values are in tons)

| Biomass / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 23602000 | 29530000 | 28239000 | 23839000 | 27939000 | 22810000 | 23331000 | 24933000 | 22280000 | 21410000 | 24336000 | 23179000 | 16340000 | 16093000 | 20831000 | 20162000 | 24792000 | 25067000 | 24085000 | 25441000 | 24934000 | 23012000 |
| Root & Tubers | 644000 | 593000 | 521000 | 790000 | 804000 | 905000 | 1045000 | 1166000 | 1490000 | 1537000 | 1568000 | 1591000 | 1760000 | 2109000 | 2353000 | 2226000 | 2237000 | 2473000 | 2427000 | 2224000 | 2129000 | 2297000 |
| Sugar Crops | 194000 | 290000 | 309000 | 371000 | 372000 | 362000 | 278000 | 400000 | 335000 | 348000 | 365000 | 391000 | 442000 | 436000 | 456000 | 514000 | 599000 | 650000 | 592000 | 651000 | 475000 | 617000 |
| Pulses | 375000 | 434000 | 639000 | 842000 | 1070000 | 1490000 | 1279000 | 1308000 | 1692000 | 2100000 | 2698000 | 2869000 | 1418000 | 1781000 | 2333000 | 3265000 | 3441000 | 3513000 | 3129000 | 4196000 | 4311000 | 4315000 |
| Treenuts | 5000 | 4000 | 3000 | 5000 | 4000 | 4000 | 5000 | 6000 | 5000 | 3000 | 4000 | 5000 | 6000 | 5000 | 6000 | 6000 | 5000 | 6000 | 6000 | 6000 | 7000 | 8000 |
| Oil Bearing Crops | 2964000 | 2918000 | 3065000 | 4031000 | 5600000 | 5815000 | 4626000 | 5170000 | 7051000 | 6380000 | 6288000 | 6301000 | 4559000 | 5759000 | 6362000 | 7031000 | 9317000 | 9825000 | 10939000 | 12450000 | 13610000 | 13957000 |
| Vegetables | 206000 | 206000 | 210000 | 227000 | 296000 | 357000 | 366000 | 432000 | 508000 | 533000 | 571000 | 650000 | 673000 | 770000 | 833000 | 807000 | 813000 | 830000 | 870000 | 846000 | 931000 | 937000 |
| Fruits | 272000 | 355000 | 267000 | 215000 | 272000 | 342000 | 434000 | 457000 | 307000 | 378000 | 422000 | 432000 | 461000 | 659000 | 660000 | 611000 | 538000 | 582000 | 737000 | 525000 | 470000 | 711000 |
| Fibre Crops | 277 | 451 | 437 | 734 | 924 | 417 | 247 | 75 | 93 | 43 | 15 | 2 | 27 | 14 | 20 | 8 | 77 | 379 | 34709 | 35761 | 20514 | 24066 |
| Tobacco and Products | 20528 | 31188 | 43645 | 47243 | 26172 | 28952 | 40169 | 36514 | 33049 | 25163 | 21659 | 27757 | 22602 | 23750 | 22195 | 19112 | 25555 | 32322 | 16868 | 15696 | 23046 | 23831 |
| Spices | 1000 | 1000 | 1000 | 1000 | 3000 | 4000 | 5000 | 8000 | 7000 | 10000 | 10000 | 9000 | 9000 | 10000 | 10000 | 12000 | 10000 | 15000 | 12000 | 11000 | 10000 | 9000 |
| Straw | 1682 | 812 | 746 | 1423 | 2233 | 2912 | 5128 | 4838 | 3385 | 1088 | 857 | 1491 | 1696 | 1755 | 3580 | 4862 | 4528 | 2847 | 7107 | 6348 | 6840 | 19737 |
| Animal Feed | 910755 | 967257 | 1071319 | 929659 | 979213 | 1021253 | 975363 | 860299 | 777427 | 802085 | 805866 | 950196 | 696378 | 607642 | 686136 | 623316 | 618884 | 715474 | 598438 | 812784 | 916456 | 833817 |
| Live Animals | 592343.09 | 633565.0557 | 761867.0837 | 750369.662 | 673316.2912 | 850128.4915 | 1176934 | 1168723 | 1281571 | 1118157 | 1139388 | 1459171 | 1706100 | 1376645 | 1289535 | 1508160 | 1801720 | 2161248 | 2150360 | 1470517 | 1391490 | 1218699 |
| Meat | 434000 | 404000 | 474000 | 520000 | 556000 | 646000 | 737000 | 863000 | 940000 | 1123000 | 1268000 | 1407000 | 1588000 | 1487000 | 1673000 | 1819000 | 1701000 | 1661000 | 1817000 | 1784000 | 1859000 | 1817000 |
| Animal Fat | 276000 | 270000 | 307000 | 247000 | 228000 | 286000 | 295000 | 317000 | 327000 | 370000 | 341000 | 393000 | 371000 | 296000 | 459000 | 405000 | 430000 | 429000 | 403000 | 400000 | 398000 | 334000 |
| Eggs | 5000 | 5000 | 4000 | 10000 | 8000 | 9000 | 8000 | 10000 | 8000 | 11000 | 15000 | 16000 | 21000 | 19000 | 18000 | 20000 | 19000 | 14000 | 13000 | 10000 | 12000 | 10000 |
| Milk | 703000 | 635000 | 543000 | 376000 | 562000 | 729000 | 711000 | 785000 | 889000 | 857000 | 620000 | 895000 | 934000 | 867000 | 360000 | 208000 | 279000 | 287000 | 234000 | 228000 | 169000 | 232000 |
| Timber Industrial Roundwood | 50386006 | 51869397.81 | 55014685.82 | 58004519.1 | 62876365.98 | 65788063.74 | 66826687 | 69969006 | 75385628 | 78936881 | 82905977 | 80755311 | 84864373 | 84631523 | 89163245 | 88108619 | 84183595 | 71095728 | 62538663 | 51566390 | 55903396 | 59211452 |
| Fuel Wood and Other Extraction | 102733.33 | 72000 | 217232.5942 | 454047.652 | 593455.0725 | 487194.2029 | 525718.8 | 399763.8 | 419981.2 | 473068.8 | 449912.8 | 604231.9 | 575183.3 | 536915.9 | 826016.5 | 1281738 | 330065.7 | 1444653 | 1344373 | 1393714 | 1645282 | 1700388 |
| Alcoholic Beverages | 405000 | 385000 | 347000 | 385000 | 455000 | 435000 | 444000 | 442000 | 463000 | 478000 | 522000 | 580000 | 530000 | 516000 | 494000 | 484000 | 534000 | 590000 | 573000 | 512000 | 584000 | 533000 |
| Stimulant | 49000 | 64000 | 102000 | 138000 | 111000 | 125000 | 122000 | 155000 | 196000 | 210000 | 222000 | 234000 | 249000 | 271000 | 281000 | 274000 | 273000 | 259000 | 228000 | 218000 | 253000 | 275000 |
| Fish-Seafood | 1202000 | 1071000 | 1011000 | 879000 | 755000 | 676000 | 767000 | 790000 | 806000 | 831000 | 815000 | 899000 | 985000 | 1013000 | 1042000 | 1060000 | 1054000 | 979000 | 911000 | 863000 | 925000 | 925000 |
| Aquatic Products-Other | 2000 | 2000 | 2000 | 0 | 0 | 1000 | 1000 | 1000 | 2000 | 1000 | 1000 | 1000 | 1000 | 1000 | 2000 | 2000 | 3000 | 2000 | 3000 | 5000 | 4000 | 4000 |
| Textile | 9760 | 7426 | 4714 | 5108 | 4502 | 5296 | 8061 | 6389 | 6081 | 8095 | 6710 | 5685 | 2912 | 3350 | 4980 | 3317 | 2521 | 4794 | 3725 | 1374 | 1523 | 1858 |

# Appendix II

## Energy Flows Table

(All values in TJ i.e. $10^{12}$ Joules)

## Biomass Energy Flows

| Biomass | | | | |
|---|---|---|---|---|
| | Production Biomass | Import Biomas | Export Biomass | DEC Biomass |
| 1990 | 4540612.417 | 180452.539 | 1537520.302 | 3183544.654 |
| 1991 | 4451608.773 | 184503.3492 | 1671864.139 | 2964247.983 |
| 1992 | 4447214.999 | 246994.931 | 1717008.95 | 2977200.981 |
| 1993 | 4655783.803 | 259876.7551 | 1714531.199 | 3201129.36 |
| 1994 | 4616359.685 | 295027.6378 | 1926117.22 | 2985270.103 |
| 1995 | 4793542.694 | 335962.3049 | 1906895.199 | 3222609.8 |
| 1996 | 5150498.351 | 332645.7796 | 1914102.901 | 3569041.229 |
| 1997 | 4919955.378 | 400249.2442 | 2018069.716 | 3302134.906 |
| 1998 | 4848597.184 | 433457.0095 | 2127324.494 | 3154729.699 |
| 1999 | 5149588.917 | 444267.4297 | 2175453.061 | 3418403.285 |
| 2000 | 5113609.573 | 555683.0754 | 2310616.125 | 3358676.523 |
| 2001 | 4625529.671 | 612220.6495 | 2273452.69 | 2964297.63 |
| 2002 | 4456736.709 | 583341.9048 | 2161383.961 | 2878694.653 |
| 2003 | 4765455.944 | 581840.1105 | 2176460.654 | 3170835.4 |
| 2004 | 5256590.68 | 578166.7176 | 2371093.412 | 3463663.986 |
| 2005 | 5319667.28 | 591141.4463 | 2378250.593 | 3532558.133 |
| 2006 | 4994614.011 | 536115.7545 | 2427667.284 | 3103062.482 |
| 2007 | 4694703.647 | 561042.2375 | 2225783.017 | 3029962.867 |
| 2008 | 4796558.372 | 599235.6133 | 2058133.816 | 3337660.169 |
| 2009 | 4294383.678 | 513489.7708 | 1917199.335 | 2890674.114 |
| 2010 | 4462954.351 | 525261.5333 | 2016752.572 | 2971463.312 |
| 2011 | 4483885.418 | 511673.2957 | 2048166.144 | 2947392.569 |

## Technical Energy Flows

| Technical Energy | | | | |
|---|---|---|---|---|
| Year | Production | Import | Export | DEC |
| 1990 | 11733989.51 | 2043003.913 | 4736999.191 | 9039994.232 |
| 1991 | 12148366.95 | 1957141.108 | 5413809.126 | 8691698.936 |
| 1992 | 12597548.04 | 1957357.36 | 5760522.502 | 8794382.903 |
| 1993 | 13484531.52 | 1950179.216 | 6206998.647 | 9227712.086 |
| 1994 | 14398009.13 | 2025817.582 | 6865476.014 | 9558350.7 |
| 1995 | 14965072.27 | 1994870.483 | 7420157.85 | 9539784.902 |
| 1996 | 15402752.76 | 2281340.325 | 7745314.895 | 9938778.187 |
| 1997 | 15774169.31 | 2601718.394 | 8126122.613 | 10249765.09 |
| 1998 | 15909464.62 | 2775951.075 | 8470545.179 | 10214870.51 |
| 1999 | 15833426.03 | 2872140.305 | 8483373.215 | 10222193.12 |
| 2000 | 16209562.27 | 3173649.035 | 8996155.757 | 10387055.54 |
| 2001 | 16379514.64 | 3389686.05 | 9272469.012 | 10496731.67 |
| 2002 | 16708481.08 | 3245645.687 | 9458113.749 | 10496013.02 |
| 2003 | 16788640.11 | 3543313.21 | 9433952.086 | 10898001.24 |
| 2004 | 17200917.17 | 3606760.096 | 9733778.687 | 11073898.58 |
| 2005 | 17265531.66 | 3657085.719 | 9778586.345 | 11144031.03 |
| 2006 | 17604672.13 | 3503703.252 | 9955211.637 | 11153163.75 |
| 2007 | 17634345.4 | 3543090.539 | 10474314.19 | 10703121.75 |
| 2008 | 17348718.46 | 3797744.42 | 10467132.35 | 10679330.53 |
| 2009 | 16636112.24 | 3511509.349 | 9976757.49 | 10170864.1 |
| 2010 | 16877854.33 | 3486439.263 | 10239089.76 | 10125203.83 |
| 2011 | 17449668.07 | 3867922.855 | 10731606.16 | 10585984.76 |

# Biomass Energy Flows DE Category Wise

| Biomass / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 1053158.6 | 998485 | 920440.3 | 954470.4 | 864257.3 | 914816.3 | 1084451 | 918767.1 | 945375 | 1002569 | 947190 | 804454.4 | 668291.2 | 911939 | 941401.9 | 944816.9 | 900598.4 | 891912.6 | 1038744 | 918670.7 | 846546.5 | 876873.4 |
| Root & Tubers | 14985.267 | 14112.27 | 17992.89 | 16538.46 | 18338.05 | 19123.12 | 20373.06 | 20804 | 21592.07 | 21287.82 | 22780.81 | 21050.55 | 23468.12 | 26347.51 | 26110.18 | 22115.91 | 25393.45 | 24936 | 23564.54 | 22849.6 | 22054.8 | 20789.91 |
| Sugar Crops | 3262.2489 | 3758.671 | 2687.19 | 2712.132 | 3780.495 | 3557.4 | 3582.689 | 2199.775 | 3048.507 | 2577.028 | 2844.118 | 1885.571 | 1194.114 | 2357.05 | 2577.028 | 2105.548 | 3016.983 | 2639.73 | 1194.114 | 2278.413 | 1939.959 | 2684.765 |
| Pulses | 12331.541 | 18835.77 | 20837.07 | 30606.02 | 43520.36 | 44074.85 | 36116.32 | 48937.26 | 64459.95 | 72608.1 | 93394.71 | 70749.75 | 46057.24 | 59692.14 | 90344.41 | 96482.85 | 79133.35 | 87895.34 | 104010.9 | 109081.4 | 112411.3 | 90890.99 |
| Treenuts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oil Bearing Crops | 122840.64 | 139830.4 | 124669.3 | 175489.7 | 231370.8 | 215763.2 | 177956.3 | 219782 | 251188.6 | 275280.4 | 232412.7 | 161157.9 | 166899.1 | 216252.3 | 246149.1 | 295587.3 | 291823.6 | 280298.6 | 363992.7 | 375113.7 | 378579.7 | 402799.1 |
| Vegetables | 3936.1128 | 3359.513 | 3447.722 | 3659.919 | 4080.513 | 4063.133 | 4201.9 | 4157.632 | 4319.917 | 4366.011 | 4169.671 | 4227.598 | 4360.09 | 4482.05 | 4628.248 | 4488.738 | 4617.393 | 4710.445 | 4399.088 | 4340.906 | 4244.329 | 4187.118 |
| Fruits | 3440.8085 | 3247.863 | 3558.257 | 3106.023 | 3549.401 | 3856.189 | 3387.774 | 3276.306 | 3248.014 | 4090.036 | 3665.363 | 3340.596 | 3023.901 | 3039.373 | 3214.389 | 3089.495 | 3272.236 | 3262.066 | 3454.389 | 3551.957 | 3126.527 | 3442.719 |
| Fibre Crops | 1086.3074 | 897.6981 | 755.4681 | 682.2918 | 822.4605 | 1089.399 | 1512.997 | 1458.373 | 1497.538 | 1404.779 | 1141.963 | 1213.078 | 721.4565 | 700.8435 | 659.6174 | 884.2996 | 1340.879 | 795.6635 | 566.8587 | 587.4718 | 587.4718 | 587.4718 |
| Other Crops | 1074.326 | 1340.91 | 1118.334 | 1319.988 | 1195.002 | 1264.497 | 1195.189 | 1298.316 | 1246.761 | 1196.28 | 903.1515 | 998.4926 | 929.389 | 789.4781 | 722.896 | 732.6073 | 826.7388 | 749.6447 | 761.8775 | 782.8846 | 683.5396 | 572.03 |
| Spices | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18.77633 | 75.10531 | 75.10531 | 93.88164 | 84.49348 | 75.10531 | 103.2698 | 65.71715 | 75.10531 | 75.10531 | 75.10531 |
| Straw | 870150.75 | 824977.8 | 760494.9 | 788611.6 | 714074.9 | 755848.2 | 896005.3 | 759112.5 | 781096.7 | 828352.3 | 782596.3 | 664664 | 552161.9 | 753470.9 | 777814.1 | 780635.6 | 744101 | 736924.5 | 858240.6 | 759032.8 | 699441.7 | 724498.7 |
| Other Crop residues | 24442.123 | 30667.26 | 27731.08 | 37695.66 | 49306.1 | 44848.71 | 37088.13 | 45121.16 | 52573.89 | 58571.2 | 50007.04 | 33999.25 | 33410.88 | 45981.25 | 53199.05 | 62995.16 | 62406.07 | 62618.17 | 79876.47 | 82514.35 | 84341.15 | 91780.34 |
| Fodder Crops | 582285.86 | 517912.4 | 491053.5 | 524591.1 | 559323.6 | 479564.8 | 489239.4 | 378677.7 | 396883.7 | 451974.6 | 430146 | 370856.9 | 334189.2 | 409289.6 | 466872.6 | 405046.6 | 422101.6 | 432501.7 | 439717.3 | 457220.8 | 448731.8 | 448808.5 |
| Grazed Biomass | 350572.76 | 419029.6 | 486508.9 | 454390.7 | 431395 | 565472 | 610620.2 | 720196.1 | 697452.1 | 632736.6 | 654137.4 | 750619.4 | 792412.2 | 696832.9 | 726833.6 | 815870 | 777310.8 | 727769 | 700288.9 | 626932 | 622775 | 555666.8 |
| Timber Industrial Roundwood | 1836498.4 | 1809071 | 1929681 | 2010020 | 2110544 | 2185879 | 2201277 | 2217293 | 2099023 | 2296254 | 2400388 | 2209230 | 2351972 | 2146446 | 2478313 | 2414568 | 2183651 | 1931704 | 1634586 | 1366416 | 1668524 | 1768574 |
| Fuel Wood and Other Extraction | 88775.28 | 95910.32 | 91224.32 | 91578.96 | 83960.8 | 75812.88 | 76969.2 | 73634 | 43831.92 | 41446.24 | 41929.36 | 41613.44 | 41041.44 | 41042.32 | 40286.4 | 41129.44 | 41959.28 | 45595.44 | 44612.48 | 42623.68 | 45622.79 | 19380.41 |
| Alcoholic Beverages | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stimulant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fish-Seafood | 21767.059 | 19541.18 | 17237.65 | 15335.29 | 13911.76 | 11763.53 | 12475.29 | 13445.88 | 14041.18 | 14494.12 | 14468.24 | 15374.12 | 15904.71 | 16409.41 | 16965.88 | 16202.35 | 16085.88 | 15141.18 | 14170.59 | 14183.53 | 13963.53 | 13963.53 |
| Aquatic Products-Other | 595.29412 | 504.7059 | 569.4118 | 388.2353 | 491.7647 | 478.8235 | 440 | 569.4118 | 478.8235 | 517.6471 | 556.4706 | 543.5294 | 621.1765 | 685.8824 | 621.1765 | 621.1765 | 672.9412 | 349.4118 | 349.4118 | 672.9412 | 608.2353 | 608.2353 |

# Biomass Energy Flows Imports Category Wise

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 22154.69 | 15461.93 | 27178.89 | 29236.78 | 28699.13 | 34576.15 | 34427.83 | 38932.93 | 43957.13 | 39674.51 | 49759.99 | 85429.97 | 100632.4 | 95089.05 | 61866.28 | 65110.69 | 61717.96 | 77884.4 | 82630.51 | 66501.15 | 60790.99 | 51354.39 |
| Root & Tubers | 1152.176 | 967.6281 | 1516.283 | 1586.112 | 1875.403 | 1700.831 | 1705.819 | 1935.256 | 2030.024 | 1795.598 | 2005.085 | 2035.012 | 2448.997 | 2149.73 | 1850.464 | 1990.122 | 2124.792 | 2015.061 | 2224.547 | 2493.887 | 2803.129 | 2848.019 |
| Sugar Crops | 4333.73 | 4188.233 | 4212.482 | 4714.793 | 4728.65 | 4371.836 | 5237.889 | 4808.327 | 5102.785 | 4229.803 | 5473.456 | 5809.484 | 5913.411 | 6796.785 | 5532.347 | 6457.292 | 6436.507 | 6332.58 | 6609.717 | 5573.918 | 5490.777 | 6148.977 |
| Pulses | 588.6177 | 588.6177 | 630.6619 | 651.6839 | 693.728 | 777.8163 | 988.0369 | 1114.169 | 1177.235 | 2039.14 | 1450.522 | 1513.588 | 2102.206 | 1997.096 | 1534.611 | 2922.067 | 2270.383 | 2186.294 | 2249.361 | 2501.625 | 3111.265 | 2522.647 |
| Treenuts | 2038.95 | 2178.604 | 2122.742 | 2346.189 | 2178.604 | 1787.572 | 1983.088 | 1927.226 | 2318.258 | 2318.258 | 2569.635 | 2848.943 | 3156.182 | 3295.836 | 3603.075 | 3407.56 | 3463.421 | 4105.83 | 4105.83 | 3994.107 | 4273.415 | 4524.792 |
| Oil Bearing Crops | 12736.98 | 10419.23 | 10568.08 | 14310.5 | 9270.991 | 11184.73 | 14438.08 | 20158.03 | 15862.75 | 22624.62 | 24432.04 | 33405.34 | 35234.02 | 33341.55 | 29726.71 | 26686 | 25686.6 | 25814.18 | 28514.68 | 29939.35 | 29173.85 | 26090.61 |
| Vegetables | 2643.368 | 2806.988 | 3145.135 | 3350.569 | 3228.763 | 3296.029 | 3425.107 | 3603.27 | 3697.806 | 3863.244 | 3968.688 | 4161.395 | 4435.913 | 4370.465 | 4415.915 | 4403.189 | 4484.999 | 4603.169 | 4548.629 | 4630.439 | 4804.966 | 5114.026 |
| Fruits | 11906.05 | 12182.11 | 12435.9 | 12636.26 | 13464.43 | 13811.73 | 14662.16 | 15744.13 | 15272.16 | 15766.39 | 16305.14 | 16576.75 | 17235.72 | 17520.68 | 17703.24 | 18798.56 | 19083.52 | 21064.89 | 20370.3 | 19689.06 | 19920.59 | 20138.77 |
| Fibre Crops | 9.193418 | 21.43757 | 54.27415 | 10.45081 | 13.52216 | 9.626292 | 9.172805 | 11.5433 | 9.152192 | 12.18231 | 9.688131 | 21.35511 | 28.30171 | 19.37626 | 22.61251 | 9.296483 | 4.617322 | 5.276939 | 10.78062 | 6.802305 | 7.1115 | 3.937091 |
| Other Crops | 48.47134 | 64.35018 | 186.6274 | 205.9478 | 237.484 | 230.0557 | 294.0481 | 352.0263 | 303.5379 | 91.37146 | 145.9422 | 115.9223 | 129.6885 | 179.2843 | 150.3549 | 188.723 | 274.1485 | 372.7949 | 435.0495 | 275.3922 | 699.4014 | 612.1189 |
| Spices | 122.0461 | 122.0461 | 131.4343 | 150.2106 | 159.5988 | 159.5988 | 178.3751 | 197.1514 | 187.7633 | 215.9278 | 215.9278 | 225.3159 | 234.7041 | 225.3159 | 253.4804 | 272.2568 | 300.4213 | 309.8094 | 328.5857 | 328.5857 | 319.1976 | 347.3621 |
| Straw | 395.0006 | 600.7889 | 682.5025 | 707.2846 | 121.9959 | 105.748 | 246.5813 | 619.2251 | 177.4503 | 265.0357 | 605.4572 | 900.0163 | 1009.63 | 955.9447 | 1117.804 | 1082.299 | 1103.033 | 1356.325 | 1422.119 | 1662.354 | 1474.272 | 1483.336 |
| Animal Feed | 1188.123 | 1158.389 | 1391.302 | 1348.938 | 1624.518 | 2101.246 | 2141.756 | 2262.386 | 2157.678 | 2110.371 | 1948.319 | 2582.773 | 2393.567 | 2312.897 | 2657.423 | 2808.836 | 2796.607 | 3880.495 | 5379.636 | 5694.729 | 7121.833 | 5492.187 |
| Live Animals | 2131.607 | 2458.074 | 2340.206 | 2139.8 | 2275.502 | 1988.496 | 1650.906 | 2391.108 | 2861.038 | 3013.849 | 3590.21 | 3257.078 | 2221.27 | 1572.428 | 1834.64 | 1927.39 | 1799.607 | 2355.028 | 2738.549 | 2588.432 | 2791.113 | 3059.393 |
| Meat | 3649.412 | 4011.765 | 4141.176 | 4982.353 | 5344.706 | 4969.412 | 5008.235 | 5681.176 | 5862.353 | 6263.529 | 6625.882 | 7492.941 | 7855.294 | 7130.588 | 5370.588 | 6250.588 | 6975.294 | 8463.529 | 8774.118 | 8709.412 | 8774.118 | 9589.412 |
| Animal Fat | 1760 | 2120 | 2520 | 2960 | 3640 | 4560 | 5200 | 4440 | 5440 | 6040 | 5160 | 7360 | 6280 | 6200 | 6280 | 5760 | 5560 | 5600 | 5640 | 6560 | 7560 | 7280 |
| Eggs | 480 | 540 | 540 | 630 | 690 | 780 | 840 | 1140 | 1470 | 1050 | 930 | 1380 | 990 | 780 | 1380 | 960 | 810 | 780 | 960 | 1140 | 1050 | 960 |
| Milk | 8275 | 8000 | 8475 | 9250 | 10300 | 8500 | 8725 | 8650 | 8475 | 9925 | 16550 | 15975 | 17800 | 20350 | 18300 | 16425 | 15175 | 16525 | 20525 | 11925 | 12900 | 13425 |
| Timber Industrial Roundwood | 91126.24 | 103535.1 | 149406.6 | 151883.7 | 187239.4 | 222072 | 208681.2 | 261017.5 | 291187.7 | 294103.5 | 382917.2 | 387085.7 | 341301.6 | 342986.2 | 377495.8 | 384732.4 | 334653.5 | 321875.4 | 344175.6 | 287008.1 | 291971.4 | 277640.3 |
| Fuel Wood and Other Extraction | 161.8824 | 175.0588 | 1208.438 | 1188.259 | 1537.473 | 1657.262 | 1567.7 | 2134.261 | 1773.995 | 2056.552 | 1224.717 | 1674.411 | 1819.976 | 1460.379 | 3931.826 | 6360.921 | 6358.67 | 8079.495 | 11263.9 | 13762.32 | 12055.9 | 10565.81 |
| Alcoholic Beverages | 7540 | 7163 | 6960 | 7076 | 7540 | 8149 | 9367 | 10788 | 12093 | 14007 | 14848 | 16704 | 16008 | 19807 | 19952 | 21808 | 21576 | 35699 | 37294 | 30334 | 37700 | 50663 |
| Stimulant | 1012 | 1064.8 | 1166 | 1227.6 | 1315.6 | 1271.6 | 1364 | 1447.6 | 1680.8 | 1672 | 1716 | 1795.2 | 1742.4 | 1830.4 | 2129.6 | 1962.4 | 2204.4 | 2208.8 | 2164.8 | 2134 | 2455.2 | 2631.2 |
| Fish-Seafood | 5034.118 | 4762.353 | 6095.294 | 7402.353 | 8994.118 | 8010.588 | 10598.82 | 11000 | 10456.47 | 11297.65 | 13368.24 | 13976.47 | 12591.76 | 11621.18 | 11427.06 | 11232.94 | 12009.41 | 11220 | 10547.06 | 10922.35 | 12048.24 | 12048.24 |
| Aquatic Products-Other | 25.88235 | 25.88235 | 25.88235 | 0 | 0 | 12.94118 | 12.94118 | 12.94118 | 25.88235 | 12.94118 | 12.94118 | 12.94118 | 12.94118 | 12.94118 | 25.88235 | 25.88235 | 38.82353 | 25.88235 | 38.82353 | 64.70588 | 51.76471 | 51.76471 |

# Biomass Energy Flows Exports Category Wise

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereal | 437569.05 | 547471.1491 | 523536.6671 | 441962.91 | 517974.82 | 422885.7742 | 432544.8 | 462245.1 | 413059.8 | 396930.5 | 451177 | 429726.8 | 302935.3 | 298356 | 386196.1 | 373793.2 | 459631 | 464729.4 | 446523.6 | 471663.2 | 462263.7 | 426630.8 |
| Root & Tubers | 3212.1262 | 2957.749742 | 2598.630043 | 3940.34114 | 4010.16997 | 4513.935103 | 5212.223 | 5815.744 | 7431.783 | 7666.208 | 7820.829 | 7935.548 | 8778.482 | 10519.21 | 11736.23 | 11102.78 | 11157.65 | 12334.76 | 12105.33 | 11092.81 | 10618.97 | 11456.92 |
| Sugar Crops | 672.05723 | 1004.621625 | 1070.441663 | 1285.22284 | 1288.68705 | 1254.044925 | 963.0511 | 1385.685 | 1160.511 | 1205.546 | 1264.438 | 1354.507 | 1531.182 | 1510.397 | 1579.681 | 1780.605 | 2075.063 | 2251.738 | 2050.814 | 2255.202 | 1645.501 | 2137.419 |
| Pulses | 7883.2732 | 9123.574828 | 13433.0975 | 17700.576 | 22493.60614 | 31322.8721 | 26887.22 | 27496.86 | 35569.33 | 44146.33 | 56717.52 | 60312.3 | 29809.28 | 37440.29 | 49044.47 | 68637.03 | 72336.91 | 73850.5 | 65778.03 | 88208.57 | 90626.11 | 90710.2 |
| Treenuts | 139.65409 | 111.7232681 | 83.79245105 | 139.654085 | 111.7232681 | 111.7232681 | 139.6541 | 167.5849 | 139.6541 | 83.79245 | 111.7233 | 139.6541 | 167.5849 | 139.6541 | 167.5849 | 167.5849 | 139.6541 | 167.5849 | 167.5849 | 167.5849 | 195.5157 | 223.4465 |
| Oil Bearing Crops | 63025.731 | 62047.59852 | 65173.36856 | 85714.1431 | 119076.954 | 123648.6585 | 98366.07 | 109933.5 | 149930.6 | 135662.7 | 133706.4 | 133982.8 | 96941.4 | 122457.9 | 135279.9 | 149505.4 | 198114.3 | 208916.3 | 232604.1 | 264733.6 | 289399.5 | 296778 |
| Vegetables | 374.5074 | 374.5074046 | 381.7793931 | 412.685344 | 538.1271445 | 649.0249682 | 665.3869 | 785.3748 | 923.5425 | 968.9925 | 1038.076 | 1181.698 | 1223.512 | 1399.858 | 1514.392 | 1467.124 | 1478.032 | 1508.938 | 1581.657 | 1538.026 | 1692.555 | 1703.463 |
| Fruits | 1211.0867 | 1580.646191 | 1188.824037 | 957.292764 | 1211.086659 | 1522.763373 | 1932.396 | 2034.804 | 1366.925 | 1683.054 | 1878.965 | 1923.491 | 2052.614 | 2934.214 | 2938.666 | 2720.492 | 2395.458 | 2591.369 | 3281.511 | 2337.575 | 2092.687 | 3165.745 |
| Fibre Crops | 5.7098132 | 9.296482908 | 9.00790029 | 15.1299744 | 19.04645279 | 8.595639407 | 5.091422 | 1.545978 | 1.917013 | 0.886361 | 0.309196 | 0.041226 | 0.556552 | 0.288583 | 0.412261 | 0.164904 | 1.587204 | 7.812344 | 715.4581 | 737.1431 | 422.856 | 496.0735 |
| Other Crops | 349.74331 | 531.3617731 | 743.5964021 | 804.896891 | 445.9022806 | 493.2661939 | 684.3745 | 622.1029 | 563.0683 | 428.7116 | 369.0126 | 472.9065 | 385.0788 | 404.6377 | 378.1446 | 325.6184 | 435.3902 | 550.6822 | 287.3865 | 267.4187 | 392.6434 | 406.0178 |
| Spices | 9.3881641 | 9.388164144 | 9.388164144 | 9.38816414 | 28.16449243 | 37.55265658 | 46.94082 | 75.10531 | 65.71715 | 93.88164 | 93.88164 | 84.49348 | 84.49348 | 93.88164 | 93.88164 | 112.658 | 93.88164 | 140.8225 | 112.658 | 103.2698 | 93.88164 | 84.49348 |
| Straw | 30.672219 | 14.80727817 | 13.60373093 | 25.9492079 | 40.72001496 | 53.10196309 | 93.51197 | 88.22366 | 61.72738 | 19.84029 | 15.62788 | 27.18923 | 30.92752 | 32.00342 | 65.28332 | 88.66131 | 82.57063 | 51.91665 | 129.6002 | 115.7594 | 124.7313 | 359.9153 |
| Animal Feed | 3648.1633 | 3874.490381 | 4291.32605 | 3723.88605 | 3922.3819 | 4090.779312 | 3906.96 | 3446.054 | 3114.098 | 3212.87 | 3228.015 | 3806.15 | 2789.445 | 2434 | 2748.419 | 2496.784 | 2479.031 | 2865.936 | 2397.132 | 3255.726 | 3670.999 | 3339.977 |
| Live Animals | 7665.6164 | 8199.077191 | 9859.456377 | 9710.66622 | 8713.504945 | 11001.66283 | 15230.9 | 15124.66 | 16585.04 | 14470.26 | 14745.02 | 18883.39 | 22078.94 | 17815.41 | 16688.11 | 19517.36 | 23316.38 | 27969.09 | 27828.19 | 19030.23 | 18007.52 | 15771.39 |
| Meat | 5616.4706 | 5228.235294 | 6134.117647 | 6729.41176 | 7195.294118 | 8360 | 9537.647 | 11168.24 | 12164.71 | 14532.94 | 16409.41 | 18208.24 | 20550.59 | 19243.53 | 21650.59 | 23540 | 22012.94 | 21495.29 | 23514.12 | 23087.06 | 24057.65 | 23514.12 |
| Animal Fat | 11040 | 10800 | 12280 | 9880 | 9120 | 11440 | 11800 | 12680 | 13080 | 14800 | 13640 | 15720 | 14840 | 11840 | 18360 | 16200 | 17200 | 17160 | 16120 | 16000 | 15920 | 13360 |
| Eggs | 150 | 150 | 120 | 300 | 240 | 270 | 240 | 300 | 240 | 330 | 450 | 480 | 630 | 570 | 540 | 600 | 570 | 420 | 390 | 300 | 360 | 300 |
| Milk | 17575 | 15875 | 13575 | 9400 | 14050 | 18225 | 17775 | 19625 | 22225 | 21425 | 15500 | 22375 | 23350 | 21675 | 9000 | 5200 | 6975 | 7175 | 5850 | 5700 | 4225 | 5800 |
| Timber Industrial Roundwood | 948442.47 | 976365.1353 | 1035570.557 | 1091849.77 | 1183555.124 | 1238363.553 | 1257914 | 1317064 | 1419024 | 1485871 | 1560583 | 1520100 | 1597447 | 1593064 | 1678367 | 1658515 | 1584632 | 1338273 | 1177198 | 970661.5 | 1052299 | 1114569 |
| Fuel Wood and Other Extraction | 1933.8039 | 1355.294118 | 4089.084126 | 8546.77934 | 11170.91901 | 9170.714408 | 9895.884 | 7524.965 | 7905.528 | 8904.825 | 8468.947 | 11373.78 | 10826.98 | 10106.65 | 15548.55 | 24126.84 | 6213.001 | 27193.47 | 25305.85 | 26234.61 | 30970.01 | 32007.31 |
| Alcoholic Beverages | 11745 | 11165 | 10063 | 11165 | 13195 | 12615 | 12876 | 12818 | 13427 | 13862 | 15138 | 16820 | 15370 | 14964 | 14326 | 14036 | 15486 | 17110 | 16617 | 14848 | 16936 | 15457 |
| Stimulant | 215.6 | 281.6 | 448.8 | 607.2 | 488.4 | 550 | 536.8 | 682 | 862.4 | 924 | 976.8 | 1029.6 | 1095.6 | 1192.4 | 1236.4 | 1205.6 | 1201.2 | 1139.6 | 1003.2 | 959.2 | 1113.2 | 1210 |
| Fish-Seafood | 15555.294 | 13860 | 13083.52941 | 11375.2941 | 9770.588235 | 8748.235294 | 9925.882 | 10223.53 | 10430.59 | 10754.12 | 10547.06 | 11634.12 | 12747.06 | 13109.41 | 13484.71 | 13717.65 | 13640 | 12669.41 | 11789.41 | 11168.24 | 11970.59 | 11970.59 |
| Aquatic Products-Other | 25.882353 | 25.88235294 | 25.88235294 | 0 | 0 | 12.94117647 | 12.94118 | 12.94118 | 25.88235 | 12.94118 | 12.94118 | 12.94118 | 12.94118 | 12.94118 | 25.88235 | 25.88235 | 38.82353 | 25.88235 | 38.82353 | 64.70588 | 51.76471 | 51.76471 |

# Technical Energy Flows DE Category Wise

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 1671503 | 1751052 | 1558459 | 1653301 | 1737213 | 1800148 | 1832717 | 1896180 | 1658325 | 1597551 | 1516371 | 1539905 | 1435279 | 1333518 | 1418223 | 1413728 | 1434882 | 1510597 | 1506984 | 1397378 | 1489487 | 1483361 |
| Crude oil | 4149207 | 4167453 | 4366656 | 4592920 | 4772247 | 5000185 | 5148310 | 5396961 | 5653326 | 5437640 | 5660025 | 5738604 | 6014272 | 6355342 | 6579622 | 6444499 | 6772259 | 6925672 | 6842641 | 6758333 | 7101606 | 7525839 |
| Oil products | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Natural gas | 4120688 | 4352385 | 4780369 | 5270042 | 5784426 | 6059352 | 6290824 | 6404782 | 6604404 | 6720054 | 6901752 | 7084850 | 7133466 | 7032164 | 7016682 | 7170727 | 7193116 | 6963356 | 6755090 | 6302190 | 6160446 | 6158610 |
| Nuclear | 268041.6 | 312632.3 | 294323.4 | 340530.8 | 389626.1 | 353201.9 | 334893 | 297584.4 | 257512.2 | 264642.3 | 262155.1 | 276180.4 | 271979.7 | 269685.9 | 325483 | 331438.5 | 352773.5 | 336634.1 | 345767.8 | 324432.8 | 326464.1 | 337021 |
| Hydro | 1068429 | 1109963 | 1139186 | 1165019 | 1187628 | 1209525 | 1280575 | 1262739 | 1195038 | 1244987 | 1290874 | 1200146 | 1262236 | 1215009 | 1227235 | 1303142 | 1270484 | 1323531 | 1359077 | 1327383 | 1265083 | 1352713 |
| Geothermal, solar, etc. | 83.736 | 125.604 | 334.944 | 334.944 | 334.944 | 334.944 | 376.812 | 376.812 | 376.812 | 753.624 | 1130.436 | 1381.644 | 1674.72 | 3181.968 | 3600.648 | 5819.652 | 9043.488 | 11011.28 | 13816.44 | 24032.23 | 33452.53 | 39481.52 |
| Biofuels and waste | 456037 | 454757 | 458219 | 462384 | 526534 | 542326 | 515058 | 515546 | 540482 | 567799 | 577255 | 538447 | 589573 | 579739 | 630071 | 596178 | 572113 | 563543 | 525342 | 502364 | 501315 | 552642 |
| Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Heat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Technical Energy Flows Imports Category Wise

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 420751.4 | 373242.2 | 386023 | 258435.7 | 284702.4 | 305944.9 | 369540.2 | 427846.9 | 550057.4 | 568170.8 | 663189.1 | 684828.3 | 581304.1 | 570682.9 | 487960.5 | 544151.8 | 526655.4 | 463104.2 | 523614.4 | 322163.2 | 330625 | 288977.3 |
| Crude oil | 1195838 | 1213291 | 1146522 | 1321751 | 1396937 | 1343478 | 1547838 | 1737125 | 1763789 | 1870883 | 2068808 | 2057482 | 1971630 | 2017200 | 2078812 | 2059421 | 1888071 | 1905611 | 1875466 | 1798253 | 1734217 | 1646382 |
| Oil products | 338117.2 | 336486.5 | 338513.8 | 311806.4 | 278796.8 | 292943.8 | 295191.4 | 354027 | 369540.2 | 344595.7 | 324455 | 440275.1 | 382982 | 497171.5 | 542300.8 | 617839.5 | 634542.6 | 586416.4 | 698710.8 | 526831.7 | 477030.8 | 667684.4 |
| Natural gas | 24220 | 12070 | 62838 | 30895 | 40031 | 25670 | 46389 | 48394 | 30226 | 30658 | 61823 | 148953 | 251548 | 369794 | 414979 | 364392 | 368567 | 516444 | 610324 | 793914 | 873198 | 1208073 |
| Nuclear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydro | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Geothermal, solar, etc. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biofuels and waste | 61 | 113 | 140 | 119 | 146 | 122 | 108 | 119 | 123 | 181 | 150 | 119 | 236 | 165 | 395 | 441 | 792 | 1721 | 3716 | 4950 | 4087 | 2922 |
| Electricity | 64016.17 | 21938.83 | 23320.48 | 27172.33 | 25204.54 | 26711.78 | 22273.78 | 34206.16 | 62215.85 | 57652.24 | 55223.89 | 58029.05 | 57945.31 | 88299.61 | 82312.49 | 70840.66 | 85075.78 | 69793.96 | 85913.14 | 65397.82 | 67281.88 | 53884.12 |

## Technical Energy Flows Exports Category Wise

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 944982.80 | 1035373.60 | 856398.92 | 866006.53 | 970808.74 | 1039604.48 | 1055161.74 | 1116068.67 | 904172.51 | 886235.38 | 849215.25 | 779405.87 | 708142.13 | 758163.37 | 682360.26 | 751067.85 | 727665.84 | 812327.34 | 835949.71 | 746660.69 | 869752.61 | 884781.02 |
| Crude oil | 1666390.47 | 1896179.68 | 2079341.17 | 2268276.03 | 2441962.12 | 2667123.81 | 2840236.98 | 3053367.13 | 3368963.71 | 3155701.34 | 3457283.15 | 3378483.17 | 3599722.50 | 3750271.01 | 3928011.69 | 3833037.44 | 4243784.55 | 4362381.17 | 4472516.05 | 4453477.12 | 4603408.64 | 5222702.46 |
| Oil products | 522556.71 | 589369.23 | 517356.27 | 549837.02 | 514227.18 | 543490.71 | 636525.81 | 672532.29 | 631369.44 | 650276.15 | 656446.17 | 848730.47 | 912546.11 | 931673.18 | 970279.88 | 961201.14 | 917614.35 | 955559.97 | 963316.57 | 912766.47 | 901616.36 | 840092.44 |
| Natural gas | 1537221.00 | 1804035.00 | 2193148.00 | 2395257.00 | 2752595.00 | 3011066.00 | 3052458.00 | 3118037.00 | 3403358.00 | 3626971.00 | 3846343.00 | 4120413.00 | 4103366.00 | 3876239.00 | 4022042.00 | 4065936.00 | 3898243.00 | 4148026.00 | 3978374.00 | 3660085.00 | 3682104.00 | 3575218.00 |
| Nuclear | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Hydro | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Geothermal, solar, etc. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Biofuels and waste | 576.00 | 552.00 | 774.00 | 1725.00 | 2543.00 | 2454.00 | 3090.00 | 3251.00 | 2034.00 | 2537.00 | 3277.00 | 4132.00 | 4295.00 | 4855.00 | 9877.00 | 10632.00 | 14039.00 | 14815.00 | 15256.00 | 17330.00 | 22398.00 | 23337.00 |
| Electricity | 65272.21 | 88299.61 | 113504.15 | 125897.08 | 183339.97 | 156418.85 | 157842.36 | 162866.52 | 160647.52 | 161652.35 | 183591.18 | 141304.50 | 130042.01 | 112750.52 | 121207.86 | 156711.92 | 153864.90 | 181204.70 | 201720.02 | 186438.20 | 159810.16 | 185475.24 |
| Heat | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

## Biomass Technical Energy Flows DE

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary solid biofuels | 450315 | 449550 | 452420 | 454993 | 517095 | 533217 | 505829 | 501487 | 525358 | 552504 | 561335 | 522681 | 571991 | 562372 | 612179 | 581112 | 557096 | 542421 | 502617 | 479125 | 476593 | 526375 |
| Biogases | 276 | 324 | 372 | 420 | 468 | 516 | 564 | 7288 | 7402 | 7634 | 7787 | 7787 | 8005 | 8005 | 8038 | 6677 | 6677 | 12782 | 13420 | 13420 | 14710 | 15923 |
| Total | 450591 | 449874 | 452792 | 455413 | 517563 | 533733 | 506393 | 508775 | 532760 | 560138 | 569122 | 530468 | 579996 | 570377 | 620217 | 587789 | 563773 | 555203 | 516037 | 492545 | 491303 | 542298 |

## Biomass Technical Energy Flows Imports

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary solid biofuels | 61 | 113 | 140 | 119 | 146 | 122 | 108 | 119 | 123 | 181 | 150 | 119 | 236 | 165 | 395 | 441 | 792 | 1721 | 3716 | 4950 | 4087 | 2922 |
| Biogases | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 61 | 113 | 140 | 119 | 146 | 122 | 108 | 119 | 123 | 181 | 150 | 119 | 236 | 165 | 395 | 441 | 792 | 1721 | 3716 | 4950 | 4087 | 2922 |

## Biomass Technical Energy Flows Exports

| Energy Carrier / Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary solid biofuels | 576 | 552 | 774 | 1725 | 2543 | 2454 | 3090 | 3251 | 2034 | 2537 | 3277 | 4132 | 4295 | 4855 | 9877 | 10632 | 14039 | 14815 | 15256 | 17330 | 22398 | 23337 |
| Biogases | | | | | | | | | | | | | | | | | | | | | | |
| Total | 576 | 552 | 774 | 1725 | 2543 | 2454 | 3090 | 3251 | 2034 | 2537 | 3277 | 4132 | 4295 | 4855 | 9877 | 10632 | 14039 | 14815 | 15256 | 17330 | 22398 | 23337 |