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Life Cycle Assessment of Cookstove Fuels in India and China

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FINAL REPORT LIFE CYCLE ASSESSMENT OF COOKSTOVE FUELS IN INDIA AND CHINA

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NOTICE

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ABSTRACT

Over half of the population in both China and India use traditional cookstoves that emit harmful air pollutants resulting in over a million annual premature deaths. Reducing pollution from cookstoves is a key priority as emissions from traditional cookstoves and open fires with solid fuels is a major health concern. Past studies have focused on the impacts of replacing “dirtier” stoves with “cleaner” stoves; however, less research is available on the full supply chain of the fuels used in the stoves. Use of traditional cookstoves fuels such as firewood and coal, combined with rapid rates of urbanization and industrialization, have contributed to resource depletion, deforestation, desertification, and biodiversity loss. The U.S. Environmental Protection Agency (U.S. EPA) is conducting research to provide data and tools that inform decisions regarding clean cookstoves and fuels for these countries. A life cycle assessment (LCA) was conducted to compare the environmental footprint of current and possible fuels used for cooking in China and India. This report provides the life-cycle inventory (LCI) environmental tradeoffs for cooking fuels on the basis of 1 gigajoule (GJ) of delivered cooking energy. The fuels evaluated include natural gas; liquefied petroleum gas (LPG); coal; kerosene; biomass (crop residue, dung, charcoal, firewood, wood pellets); biogas; sugarcane ethanol; and dimethyl ether (DME). The study also assessed electric stoves that utilize a diverse set of fuel types upstream. Current fuel mix profiles are compared to scenarios of projected differences in and/or cleaner cooking fuels. Results are reported for a suite of relevant life cycle impact assessment (LCIA) indicators: global climate change, energy demand, fossil depletion, water consumption, particulate matter formation, acidification, eutrophication and photochemical smog formation. Traditional fuels demonstrate notably poor relative performance in particulate matter formation, photochemical oxidant formation, freshwater eutrophication, and black carbon emissions. Most fuels demonstrate trade-offs between impact categories. Stove efficiency is found to be a crucial variable determining environmental performance across all impact categories. The study shows that electricity and many of the processed fuels, while yielding emission reductions in homes at the point of use, transfer many of those emissions upstream into the processing and distribution life cycle stage. The data presented in this report will be part of an EPA tool that provides users access to data and facilitates analyses to evaluate differences in fuels and other parameters that affect selection of future cookstove fuels. The tool will provide information on the LCA environmental tradeoffs that affect the environmental performance of cookstove fuels. The tool will also link to a Global Alliance for Clean Cookstoves’ tool – the Fuel Analysis, Comparison and Integration Tool (FACIT) – providing information on environmental, economic and social impacts associated with several types of fuels used in cookstoves.

FOREWARD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) within the Office of Research and Development (ORD) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication was produced in support of ORD’s Air, Climate, and Energy FY16-19 Strategic Research Action Plan. EPA, along with other federal partners, is working in collaboration with the Global Alliance for Clean Cookstoves to conduct research and provide tools to inform decisions about clean cookstoves and fuels in developing countries. This study scope includes a Life Cycle Assessment (LCA) comparing the environmental footprint of current and potential fuels and fuel mixes used for cooking within China and India. Study results will allow researchers and policy-makers to quantify sustainability-related metrics from a systems perspective.

Cynthia Sonich-Mullin, Director
National Risk Management Research Laboratory
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U.S. Environmental Protection Agency

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF TABLES

Page

LIST OF TABLES (Continued)

APPENDIX A TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

APPENDIX B TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

Page

LIST OF FIGURES

Page

LIST OF FIGURES (Continued)

Page

LIST OF FIGURES (Continued)

Page

Acronyms and Abbreviations

AD	Anaerobic Digester
Ag	Agricultural
AGB	Above Ground Biomass
BC	Black Carbon
BGB	Below Ground Biomass
BrC	Brown Carbon
CAP	Criteria Air Pollutants
CED	Cumulative Energy Demand
CFC	Chlorofluorocarbons
CH_4	Methane
CN	China
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_3	Carbonate
DME	Dimethyl ether
EC	Elemental Carbon
FAO	Food and Agriculture Organization
GACC	Global Alliance for Clean Cookstoves
GCCP	Global Climate Change Potential
GHG	Greenhouse Gas
GJ	Gigajoule
GSF	Gold Standard Foundation
GWP	Global Warming Potential
HAPs	Hazardous Air Pollutants
HCFC	Hydrochlorofluorocarbon
HHV	Higher Heating Value
IEA	International Energy Association
IN	India
IOCL	Indian Oil Corporation Limited
IPCC	Inter-Governmental Panel on Climate Change
LBNL	Lawrence Berkeley National Laboratory
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Inventory Assessment
ISO	International Standards Organization
LPG	Liquefied Petroleum Gas
NG	Natural Gas
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Carbon
NOx	Nitrogen Oxides
OC	Organic Carbon
ONGC	Oil and Natural Gas Corporation
P	Phosphorous
PM2.5	Particulate Matter, <2.5 micrometers
PM10	Particulate Matter, <10 micrometers
PV	Photovoltaics
QAPP	Quality Assurance Project Plan
SLCPs	Short-Lived Climate Pollutants
SO_2	Sulfur Dioxide
SOx	Sulfur Oxides
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
US LCI	United States Life Cycle Inventory
VOC	Volatile Organic Carbon

ES.1 EXECUTIVE SUMMARY

ES.1.1 Introduction

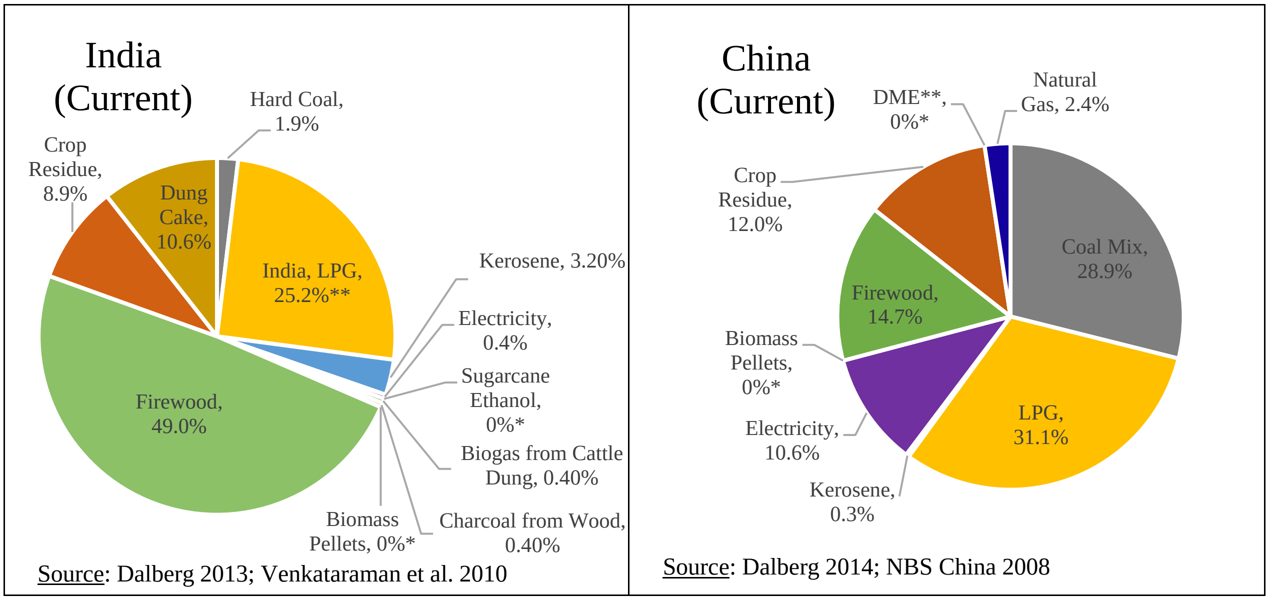
The use of traditional cookstoves in developing countries affects millions of lives on a daily basis with far-reaching health and environmental impacts. In both China and India, approximately half of each country's population (totaling more than 2.6 billion people) currently use traditional cookstove fuels (e.g., wood, crop residues, dung cake and coal). Over a million annual premature deaths in China and India are attributed to criteria air pollutants (CAPs) and hazardous air pollutants (HAPs) from these cooking fuels. Consumption of these traditional cookstove fuels, combined with rapid rates of urbanization and industrialization, has furthered the countries' resource depletion, deforestation, desertification, and biodiversity loss. The U.S. Environmental Protection Agency (U.S. EPA) is working in collaboration with the Global Alliance for Clean Cookstoves (the Alliance) and other international partners to conduct research and provide tools to inform decisions about clean cookstoves in these countries. This study scope includes a Life Cycle Assessment (LCA) comparing the environmental footprint of current and potential fuels and fuel mixes used for cooking within China and India. LCA is a tool used to quantify sustainability-related metrics from a systems perspective.

The term "clean cooking fuel" is commonly understood to represent fuels that produce less damaging emissions at the point of use. Table ES-1 and Table ES-2 provide a range of emission factors at the point of use for cooking fuel types typically considered "clean" as compared to cookstove fuel types with greater emissions during combustion. However, assessing only point of use emissions may neglect important impacts across the full life cycle of the fuel. There may be increased emissions at the point of production, processing or distribution of the fuel. Conducting an LCA of cooking fuels allows a more holistic analysis of changes in cookstove fuel mixes, which may lead to increases or decreases in environmental releases both locally and globally. The first goal of this study is, therefore, to determine the life cycle environmental burdens associated with a suite of current fuels used for cooking within China and India. The study then leverages the individual fuel profiles developed to assess the environmental impacts from the current cookstove fuel mix in each country as well as projected future cookstove fuel mix scenarios.

This study focuses on delivering information to stakeholders involved in making decisions related to optimizing cookstove fuel production, processing, distribution and use. Audiences that may benefit from the information developed through this research include, but are not limited to, local and national governments in China and India, donors and investors (e.g., strategic planners), and researchers (e.g., sustainability scientists).

ES.2.1 Methodology

This LCA investigates current fuels and fuels with market potential for cookstoves in India and China. The current India and China fuel mix for cooking, including potential fuels considered but not currently utilized in measurable quantities in these two countries, is illustrated in Figure ES-1. The environmental impacts of the fuels per country listed in Figure ES-1 are covered in this analysis.



*These fuels are not currently used at measurable quantities in the investigated countries, but are considered as potential future fuels for cooking.

**DME = dimethyl ether, a gaseous fuel type from coal gasification. LPG = liquefied petroleum gas.

Figure ES-1. Current Cooking Fuel Mix in India and China

The following life cycle stages are analyzed for each fuel system:

- **Production** of the cookstove fuel feedstock, including all stages from extraction or acquisition of the fuel feedstock from nature through production into a form ready for processing into cooking fuel (e.g., cultivation and harvesting of sugarcane, extracting crude oil from wells).

- **Processing** of the fuel into a form ready to be used in a cookstove.

- **Distribution** of fuels from the production site to the processing location and on to a retail location or directly to the consumer. Distribution also includes bottling for fuels stored in cylinders.

- **Use** of the fuel via combustion of the fuel or use of electricity in a cookstove, including disposal of any combustion wastes or residues (e.g., ash).

Cookstove production and distribution, human energy expended during collection of fuels, and the production, preparation, consumption, and disposal of food and food wastes are outside the boundaries of this project. A previous LCA examining production of fuel-efficient cookstoves found that the use phase significantly dominates life cycle greenhouse gas (GHG) emissions regardless of the combusted cooking fuel type utilized (Wilson 2016); therefore, it is reasonable to exclude processes associated with stove production and distribution from the study scope.

Results of the LCA are expressed in terms of a common reference unit, or functional unit. As this analysis is a comparison of different fuels used to provide cooking energy, an energy functional unit is a proper basis of comparison. Therefore, the LCA results are based on useful energy delivered for cooking: ***1 GJ of useful energy delivered to the pot for cooking***.

This study investigates bio-based and fossil-based cooking fuels as well as electricity (a mix of fuel types) currently used at a measurable level of capacity in India or China, as depicted in Figure ES-1. Cooking fuels not currently used, or used in only small quantities but with future market potential in these two countries, are also assessed. The current fuel use percentages are varied to show possible future cooking fuel mix scenarios for each country. These cooking fuel scenarios were chosen through review of public sources discussing possible changes in the fuels used within these countries, including the effect of policies that have been or could be put in place to increase future use of specific fuels. Eight cooking fuel mix scenarios were considered for India and for China (displayed in Table 1-5 and Table 1-8 of Chapter 1). The scenarios focus on a feasible increase of cleaner burning fuels and a decrease of traditional fuels, such as unprocessed biomass and dung cake, including:

- Increases in electricity used for cooking (used by induction cookstoves) in urban areas,
- Increases in electricity using a cleaner electricity grid (e.g. grid decrease in coal contribution and increase in contribution from natural gas, nuclear, hydropower, and other renewable fuel sources such as wind power),
- Increases of liquefied petroleum gas (LPG) use in urban and/or rural areas, and
- Increases of other cleaner burning fuels such as biomass pellets, dimethyl ether (DME), ethanol, and biogas, currently used in smaller amounts in each country.

These increases were based on the current urban or rural population that could possibly use the fuels in each country. No increases/decreases greater than 20% were considered for long-term changes to the use of cooking fuel. The cleaner electricity grid focuses on a decrease in coal use, which currently accounts for over 70% of generated electricity in each country, while increasing use of cleaner generation from hydropower, nuclear, natural gas, and wind.

Environmental impacts are presented and analyzed by life cycle stage – feedstock production, fuel processing, distribution and use – to identify those stages responsible for the largest impacts and therefore presenting the greatest opportunity for improvements. The environmental analysis was conducted in accordance with the following voluntary international standards for LCAs:

- International Standards Organization (ISO) 14040: 2006, Environmental management – Life cycle assessment – Principles and framework (ISO 2010a); and
- ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and guidelines (ISO 2010b).

The majority of life cycle inventory (LCI) data were extracted from existing studies in publicly available academic literature. An LCI is an accounting of the material, energy, and water inputs and the product, waste, emission, and water outputs for a particular product or process

(Baumann and Tillman 2004). Detailed unit process LCI data were entered into the United States Department of Agriculture (USDA) and U.S. EPA US Federal LCA Digital Commons LCI Unit Process Templates (USDA and U.S. EPA 2015) and imported into OpenLCA software (GreenDelta 2015) to calculate the life impact assessment results (LCIA). LCIA is the process of translating emissions data contained in an LCI into environmental loads, which help users to interpret cumulative environmental impacts of the studied system (Baumann and Tillman 2004). The following ten impact assessment indicators are covered in this analysis:

1. Global Climate Change Potential (GCCP)
2. Cumulative Energy Demand (CED)
3. Fossil Depletion
4. Water Depletion
5. Particulate Matter Formation Potential
6. Photochemical Oxidant Formation Potential
7. Freshwater Eutrophication Potential
8. Terrestrial Acidification Potential
9. Ozone Depletion Potential
10. Black Carbon (BC) and Short-Lived Climate Pollutants

This suite of indicators addresses global, regional, and local impact categories of relevance to the cookstove sector, such as energy demand driving depletion of bio-based and fossil-fuel-resources, greenhouse gases (GHG) and black carbon emissions causing both short-term and long-term climate effects. Of particular concern are those impact categories that directly impact human health. These include emissions resulting in black carbon, particulate matter formation, and photochemical oxidant formation, all of which can lead to eye irritation, respiratory disease, increased risks of infection, and cancer (Goedkoop et al. 2008). Table 1-10 in Section 2 provides a description of each impact category along with the relevant units used to report results. Results for each impact category are calculated using the ReCipe impact assessment methodology (Goedkoop et al. 2008). Section 1.2.9 describes the methodology in greater detail.

ES.3.1 Key Findings

Although this analysis is focused on the comparison of current and potential future fuel mix scenarios, results by life cycle stage for individual fuel use in each country are also provided. Investigating the impact of individual fuels provides insight into the differences in results observed between each of the cookstove fuel mix scenarios. Table ES-1 and Table ES-2 depict the average emissions factors for key pollutants across four broad cooking fuel types for India and China, respectively. Emission values that contribute to the averages can be found in Appendix A in Tables A-18 to A-28 and Tables A-44 to A-72 for India and China, respectively. These tables provide context for the level of magnitude differences in emissions values between broad cooking fuel type categories. Liquid and gas cookstove fuels typically have the lowest emission factors at point of use and are generally considered “clean cooking fuels”. Processed biomass fuels also lead to relatively lower air emissions during cooking compared to coal and unprocessed biomass.

Table ES-1. Average Emission Factors during Cooking (in kg/MJ) of Key Pollutants by Cookstove Fuel Category for India

Emission	Cooking Fuel Category*			
	Fossil Solid	Liquid/Gas	Processed Solid Biomass	Unprocessed Biomass
Carbon dioxide	0.86	0.12	0.29	0.89
Carbon monoxide	0.027	0.0012	0.029	0.041
Methane	0.0026	2.5E-05	8.8E-04	0.0042
Nitrogen oxides	5.5E-04	4.2E-05	1.5E-04	6.4E-04
Sulfur dioxide	0.0015	7.6E-05	3.5E-05	2.3E-04
Dinitrogen monoxide	4.4E-08	2.3E-04	8.0E-06	8.7E-05
Particulates, > 2.5 um, and < 10um	0.017	7.8E-05	3.6-04	0.013
NMVOC**	0.0058	3.1E-04	0.011	0.0086

*Fossil-solid fuel includes only coal; Liquid/gas fuel values are a direct average of point-of-use emissions for biogas, ethanol, LPG (from natural gas and crude oil), and kerosene; Processed solid biomass is a direct average of point-of-use emissions for charcoal and biomass pellets; and unprocessed biomass is a direct average of point-of-use emissions for dung cake, firewood, and crop residues.
Note: The table does not distinguish between biogenic and fossil emissions.
Sources: MacCarty 2009, Jetter et al., 2012, Singh et al. 2014.
**NMVOC = non-methane volatile organic carbon

Table ES-2. Average Emission Factors during Cooking (in kg/MJ) of Key Pollutants by Cookstove Fuel Category for China

Emission	Cooking Fuel Category*			
	Fossil Solid	Liquid/Gas	Processed Solid Biomass	Unprocessed Biomass
Carbon dioxide	0.58	0.13	0.26	0.69
Carbon monoxide	0.022	3.7E-04	9.0E-04	0.040
Methane	1.4E-03	2.0E-05	1.0E-04	0.0019
Nitrogen oxides	3.5E-04	8.8E-05	6.0E-05	4.2E-04
Particulates, < 2.5 um	8.0E-04	9.9E-06	9.0E-05	2.3E-03

* Fossil-solid fuel includes all coal types; Liquid/gas fuel values are a direct average of point-of-use emissions for LPG, kerosene, DME, and natural gas; Processed solid biomass includes biomass pellets; and unprocessed biomass is a direct average of point-of-use emissions for firewood and crop residues.
Note: The table does not distinguish between biogenic and fossil emissions.
Sources: Zhang et al. 2000, Tsai et al. 2003, Jetter et al. 2012.

Tables describing summary impact results are included below. Color gradient coding is provided to indicate the relative magnitude of results for each indicator across the fuels evaluated. Six bins are defined to aid in quantifying the variation in impact scores that exist between the studied fuels. Definitions of these bins are provided in Table ES-3.

Table ES-3. Description of Bin Cut-offs for Summary Impact Results

Bin Description	Bin Color
Values > 5 times the median	
Values between 2 and 5 times the median	
Values between 1 and 2 times the median	
Values between 0.5 and 1 times the median	
Values between 0.1 and 0.5 times the median	
Values < 0.1 times the median	

Table ES-4 depicts the environmental impact results by cooking fuel type for India, while Table ES-5 shows the equivalent results for China. For an example of interpreting the tables, in Table ES-4, the color coding indicates that biogas from dung generally has lower environmental impact compared to other fuels. The exclusive presence of dark and medium green indicates that all of the impact scores for this fuel are less than one half the median reported value for each impact category. Unprocessed dung cake shows tradeoffs (i.e., comparatively low results for fossil depletion, water depletion, and ozone depletion, but relatively high results for cumulative energy demand, particulate matter, photochemical oxidants, eutrophication, and black carbon compared to other fuels). While the colors applied show quantitative thresholds between different results' ranges, they should not be interpreted as indicators of statistically significant differences between cooking fuel types.

Table ES-4. Summary Impact Results by Cooking Fuel for India

		Per GJ Delivered Heat for Cooking									
		Global Climate Change Potential	Cumulative Energy Demand	Fossil Depletion	Water Depletion	Particulate Matter Formation Potential	Photochemical Oxidant Formation Potential	Freshwater Eutrophication Potential	Terrestrial Acidification Potential	Ozone Depletion	Black Carbon & Short Lived Climate Pollutants
		kg CO2eq	MJ	kg oil eq	m3	kg PM10eq	kg NMVOC eq	kg P eq	kg SO2 eq	kg CFC-11 eq	kg BC eq
Unprocessed solid biomass	Firewood	539	7,716	0.0064	0.049	4.72	6.02	0.16	0.40	2.6E-09	1.04
	Crop residue	132	9,670	0.0076	0.058	11.3	8.75	0.19	0.62	3.1E-09	2.42
	Dung cake	191	12,859	0.15	1.19	23.6	18.7	3.82	0.75	6.2E-08	5.01
Processed solid biomass	Charcoal from wood	572	10,209	0.12	0.63	19.5	10.5	0.28	0.21	4.5E-09	4.27
	Biomass pellets	134	2,039	6.25	35.6	0.21	0.24	0.0034	0.29	3.2E-07	0.020
Liquid/gas	Ethanol from sugarcane	95.7	6,507	18.3	88.6	0.17	0.34	0.037	0.50	6.3E-06	-0.0054
	Biogas from dung	10.5	1,820	0	1.04	0.077	0.11	0	0.11	0	0.0068
	LPG from natural gas	292	1,391	36.1	26.7	0.12	0.62	0.0021	0.31	2.3E-06	5.5E-04
	LPG from crude oil	303	2,106	53.7	31.7	0.16	0.76	0.0029	0.33	2.0E-06	0.014
	Kerosene	181	2,584	65.7	36.3	0.31	1.16	0.0033	0.40	2.4E-06	0.045
Other	Hard coal	963	13,778	243	16.6	19.3	7.86	0.0021	1.87	8.2E-07	3.91
	Electricity	415	5,443	91.4	515	1.69	2.01	0.0034	4.00	1.4E-06	-0.019
All-Fuel Median		241	5,975	12.3	21.7	1.00	1.59	0.0034	0.40	5.7E-07	0.032

Sources: Compilation of results reported in Appendix B, Tables B1-B10. Individual source documents reported in Appendix B.
*PM10 = particulate matter up to 10 micrometers in size, CFC = Chlorofluorocarbon, NMVOC = non-methane volatile organic carbon, CO2 = carbon dioxide, SO2 = sulfur dioxide, P = Phosphorus

Table ES-5. Summary Impact Results by Cooking Fuel for China

		Per GJ Delivered Heat for Cooking									
		Global Climate Change Potential	Cumulative Energy Demand	Fossil Depletion	Water Depletion	Particulate Matter Formation Potential	Photochemical Oxidant Formation Potential	Freshwater Eutrophication Potential	Terrestrial Acidification Potential	Ozone Depletion	Black Carbon & Short Lived Climate Pollutants
		kg CO2eq	MJ	kg oil eq	m3	kg PM10eq	kg NMVOC eq	kg P eq	kg SO2 eq	kg CFC-11 eq	kg BC eq
Unprocessed solid biomass	Firewood	281	6,538	0.0025	0.019	1.49	1.81	0.061	0.29	9.9E-10	0.30
	Crop residue	54.7	7,905	0.015	0.12	3.40	2.52	0.38	0.30	6.2E-09	0.69
Processed solid biomass	Biomass pellets	118	2,369	8.12	49.2	0.21	0.26	0.020	0.39	2.3E-07	0.011
Liquid/gas	LPG	188	2,784	64.4	57.1	0.20	0.40	0.0080	0.68	2.9E-05	-0.018
	Kerosene	207	2,943	67.7	72.3	0.23	0.42	0.010	0.87	3.8E-05	-0.032
	Natural gas	213	2,049	48.6	5.77	0.057	0.23	6.8E-04	0.17	3.4E-05	-0.0022
	DME	345	6,395	111	27.5	0.75	2.01	0.063	1.18	2.3E-05	0.054
Other	Coal mix	1,014	10,506	179	44.5	1.81	2.33	0.11	3.72	6.4E-06	0.043
	Electricity	496	6,060	95.6	524	1.33	1.87	0.063	4.27	2.3E-06	-0.12
All-fuel Median		213	6,060	64	45	0.75	1.81	0.06	0.68	6.37E-06	0.011

Sources: Compilation of results reported in Appendix B, Tables B11-B20. Individual source documents reported in Appendix B.

It is challenging to pin down a precise definition of what is considered a "clean" cooking fuel. As Table ES-4 and Table ES-5 clearly demonstrate, the majority of cooking fuels exhibit some trade-offs between impact categories. Biogas from dung is the only possible exception. Even for biogas from dung, a designation cannot be made in absolute terms on the basis of this research and any "clean" designations or comments regarding either favorable or unfavorable environmental performance should be understood to be relative to the selection of studied fuels within each country. In general, when this study refers to a fuel's favorable environmental performance, this should be understood to indicate that its impact scores in the referenced impact category were less than half of the median impact score. Conversely, if the study refers to a fuel having poor or unfavorable environmental performance, this indicates that the impact score is greater than two times the median impact score. Any deviations to these general interpretations are clearly expressed in the body of this report, and only apply to the example they are immediately referencing. These limitations should be kept closely in mind when interpreting the results as presented throughout the remainder of this report.

Overall, the efficiency of fuel and stove combinations was found to be a key parameter driving impact results in both countries. Fuels that can be used in stoves with higher efficiencies (e.g., LPG, kerosene, biogas, ethanol, natural gas, electricity and biomass pellets) had generally lower environmental impacts compared to low efficiency stoves burning traditional fuels (e.g., firewood, dung cake, crop residues, and coal).

In India, biogas consistently emerged as a low-impact fuel with all of its impact scores being less than 50% of the all-fuel median in each category. None of the other fuels exhibit such consistent environmentally preferable performance. Results for dung cake, firewood, charcoal, and hard coal are often found on the lower end of environmental performance. All four of these fuels have at least five of their ten impact scores that are over two times the median value associated with the respective impact category. Biomass pellets as well as kerosene and LPG tend towards favorable environmental performance with each fuel having six or more impact scores that are better than the impact category median. Ethanol from sugarcane produces low impact scores in GCCP, and the three major human health related impact categories (particulate matter formation, photochemical oxidant formation and black carbon); however, higher water depletion impacts were seen for this fuel since irrigation is required during cane production. This could be a particular challenge in India, which is currently a water-stressed nation. The traditional fuels had particularly high impacts for particulate matter formation and black carbon emissions.

In China, natural gas, biomass pellets, and LPG generally showed favorable environmental performance relative to other fuels. Each of these fuels have impact scores that are better than the median in eight or more of the ten impact categories. Coal has the lowest aggregate environmental performance with five of its ten impact scores being over two times the median value for each impact category. Since electricity generation in both China and India is dominated by coal, the electricity impacts are influenced by coal production and combustion impacts. Water impacts were also significant for electricity due to the contribution of hydroelectric power to the grid mix. Establishment of dams for hydropower leads to notable evaporative losses.

Although many of the fuels used for cooking in India and China are considered "clean" cookstove fuels, based on the reduced amount of emissions released at the point of use in the home, the LCA reveals that for many of these fuels, lower emissions at point of use are offset by impacts at the point of fuel production or processing. During the production or processing step, emissions may be released due to a thermal and/or chemical change to the feedstock, or from combustion of fuels (or generation of electricity) required to process the feedstock. Even though the immediate emission exposure risks to the person cooking are alleviated, emissions will still be released on a regional or global basis at the location of production or processing. For example, use of electric cookstoves ensures persons in the household are no longer exposed to direct emissions of the particulates in wood smoke from traditional cookstoves. However, since over 70% of electricity in India and China is generated from coal, there is a tradeoff between avoided wood smoke emissions at point of use and emissions released from combustion of coal at the power plant, which contribute to a variety of local, regional, and global environmental impacts. These tradeoffs are best exemplified in the results by cooking fuel type reported in Sections 3.1 and 4.1. Given that this study considers the full life cycle of cooking fuels rather than only point-of-use emissions, usage of the term "clean" in this report diverges from this common usage, and should be considered more comprehensive.

Given the magnitude of impacts resulting from the use of cookstoves on both the environment and human health (e.g., photochemical smog, particulate matter emissions, and black carbon impacts are all associated with a range of human health issues) it is important to consider how future changes in cookstove fuel mix scenarios might affect these impacts. As previously noted, eight potential fuel use scenarios were evaluated to explore how impacts in each of the ten studied environmental impact categories may change in the future for shifts in the national mix of cooking fuels.

Trends and observations about similarities and differences in LCA results for both India and China include the following:

- Processed biomass energy sources such as biogas from dung in India and biomass pellets in China perform well across many of the LCA results categories in comparison to both traditional and fossil fuels. Scenarios where these fuels partially displace traditional biomass show some promise of reducing point of use emissions in the home that can be harmful to human health without significant tradeoffs such as increased global climate change potential or water depletion.

- The production and use of coal requires the most energy and has the greatest amount of GCCP impact. Therefore, any reduction of coal, either as a direct fuel input for cookstoves or within the electricity grid, will result in a better environmental footprint for cooking fuel use within either country.

- Increased use of LPG in the future could also result in lower impacts for most LCA results categories in both countries. However, this is only true for certain scenarios where LPG replaces the worst performing fuels such as dung in India and coal in China.

- While increasing use of electric cookstoves will not decrease GCCP, CED, and fossil depletion impacts in India due to the large share of electricity that is generated from coal, replacing use of coal cookstoves with electric cookstoves in China does result in reductions in these impact categories largely because the efficiency of the electric cookstove is so much higher than the efficiency of the coal cookstoves used in the home, and because some portion of the grid electricity is derived from cleaner, non-fossil sources such as hydropower.

- Finally, a large portion of CED and GCCP originates from the use phase of the life cycle of the cooking fuels. The evaluated fuels have a range of heating values; however, when cooking, the amount of useful energy delivered to the cookstove depends not only on the energy content of the fuel, but also on the cookstove efficiency. If the cookstove has a low efficiency, more fuel must be used to provide a given amount of cooking energy. If more fuel is required due to the use of a low efficiency stove, the benefits of using a fuel with a low environmental profile could be offset.

This research built a framework model for examining the life cycle impacts of cookstove fuels in developing countries. This framework model can serve as the basis for further understanding the quantifiable tradeoffs between fuel choices to help spur initiatives to change cooking fuel use patterns. The model can be continually improved upon as it is enhanced with additional sensitivity and uncertainty analyses, and as more current data on cookstove fuel impacts becomes publicly available.

ES.4.1 Report Organization Summary

The remainder of this report is organized as follows:

- **Chapter 1: Goal and Scope Definition –** Discusses the overall study goal and scope, boundaries, and describes the LCA categories addressed in the study;
- **Chapter 2: Process Descriptions and Methodology –** Describes details of the LCA methodology, including allocation, data sources, and description of the fuels addressed in the study;
- **Chapter 3: Life Cycle Assessment Results for India --** Provides an analysis of all environmental results for all individual fuels, as well as all fuel mix scenarios for India;
- **Chapter 4: Life Cycle Assessment Results for China --** Provides an analysis of all environmental results for all individual fuels, as well as all fuel mix scenarios for China;
- **Chapter 5: Conclusions and Next Steps –** Describes the main LCA conclusions for each country and discusses recommendations for future work;
- **Chapter 6: References --** Lists references used in this LCA;
- **Appendix A: Detailed LCI Tables** – Presents supporting LCI data and information, including detailed tables of all energy and emissions data for all fuels at each life cycle phase with associated citations; and
- **Appendix B: Detailed LCA Result Tables –** Presents LCA tables for each individual fuel and all scenarios.

1. GOAL AND SCOPE DEFINITION

1.1 Goal

The overall goal of this study is to conduct a transparent LCA for the U.S. Environmental Protection Agency (U.S. EPA), in coordination with the Global Alliance for Clean Cookstoves (the Alliance), to facilitate the comparison of the current fuel mix used and possible future changes to the fuel mix used for cooking within India and China. The output of this effort will improve the understanding of the comparative life cycle environmental impacts and benefits that can be affected by choice of cookstove fuels. The current mix of the most common cookstove fuels for each country, as well as eight possible fuel mix changes for China and for India, are evaluated. The main study goals are to:

1. Determine the environmental burdens associated with current individual fuels used for cooking within India and China on a life cycle basis using publicly available data sources; and

2. Calculate the environmental impacts associated with use of the current and projected cooking fuel mixes used in India and China.

The environmental impacts for each fuel are reported by life cycle stage: feedstock production, fuel processing, distribution, and use in a cookstove including combustion and disposal of residuals. For each of the two countries, the environmental impacts are calculated for the current mix of cooking fuels used and compared to a number of possible projected changes (scenarios) in the fuel mix profile.

The primary intended use of this study report is to provide comparative data to inform policy decisions based on a more holistic analysis of changes in cooking fuels and stoves and the associated changes in environmental releases both locally and globally. Environmental issues surrounding cooking fuels are identified, along with opportunities to address these issues based on the choices of cooking fuels. The study also identifies areas, such as cooking fuel types or life cycle stages, where changes in the mix of fuels would be most beneficial in terms of reduced energy use, water consumption or impacts associated with environmental emissions (e.g., emissions released to air, water, and land).

The study is conducted in accordance with the following voluntary international standards for LCAs:

- ISO 14040: 2006, Environmental management – Life cycle assessment – Principles and framework (ISO 2010a); and

- ISO 14044: 2006, Environmental management – Life cycle assessment – Requirements and guidelines (ISO 2010b).

Audiences that may benefit from information developed through this research include, but are not limited to local and national governments in China and India, donors and investors (e.g., strategic planners), and researchers (e.g., sustainability scientists).

1.2 Scope of the Study

This section discusses the overall scope of the study necessary to accomplish the stated goals. The LCA components covered include the functional unit, fuel systems studied, study boundaries, scenario development, impact assessment methodology and data quality requirements.

1.2.1 Functional Unit

To provide a basis for comparison of different products, a common reference unit must be defined. The reference unit is based upon the end function of the products, so that comparisons of different products are made on a uniform basis. This common basis, or functional unit, is used to normalize the inputs and outputs of the LCA. Results of the LCA are then expressed in terms of this functional unit. As this analysis is a comparison of different fuels used to provide energy for cooking, a functional unit of cooking energy delivered is a proper basis of comparison. For this reason, the functional unit of this LCA is based on useful energy delivered: ***1,000 megajoules (MJ) (or 1 GJ) of useful energy delivered to the pot for cooking***. Useful energy refers to energy that goes into work and is not lost (e.g., through transmission or distribution or heat losses at the cookstove).

1.2.2 Geographical Scope

The geographic scope of this analysis is fuels used in cookstoves in India and China. India and China were selected because they are both Phase 1 Alliance countries, and fuel literature and LCI data are available. Phase 1 countries are those for which the Alliance has mobilized resources to grow the global market for clean cookstoves between 2012 and 2014. The Alliance selected Phase 1 countries as top priorities for clean cookstoves based on the size of the impacted population, the maturity of the market in each country, the magnitude of need, and the strength of the partner (including government).

In both China and India, approximately half of each country's population currently uses traditional cookstove fuels (i.e., coal and wood), and over a million annual premature deaths are attributed to CAPs and HAPs released from combustion of these fuels. Consumption of traditional cookstove fuels, combined with rapid rates of urbanization and industrialization, has contributed to the countries' resource depletion, deforestation, desertification, and biodiversity loss. According to the United Nations Convention to Combat Desertification, nearly 40% of the Asian continent is arid, semi-arid, and dry sub-humid land, with 27% of China's land being desertified. Deserts are expanding in both China and India (UNCCD 2015).

1.2.3 Transparency

The methods, standards, tools, and data upon which this study is based are all clearly communicated in the report body or in the appendices. Raw life cycle inventory data are included in Appendix A. Appendix B reports model output by impact category for each of the studied scenarios. Using this information in combination with the freely available OpenLCA software tool (GreenDelta 2015) will allow interested parties to recreate results using the reported methods. Reporting of results both according to fuels and scenarios allows users the flexibility to explore alternative scenarios that are not explicitly covered in this report. Reference material that was used as source data for the LCA models is clearly documented in the Appendix A tables, and an effort was made to prioritize the use of publicly available information from literature.

1.2.4 Fuel Systems Studied

This LCA considers the main cooking fuels currently used in India and China. Electricity, which is generated from a mix of sources in each country, is also included. Table 1-1 lists the fuels commonly used for cooking in these countries. The environmental impacts for each individual fuel, as well as the current mix of cooking fuels used in each country, are calculated in this analysis. This study also considers eight possible fuel mix changes for both China and India, representing potential shifts to increased use of cleaner-burning fuels, as discussed in Section 1.2.6.

Table 1-1. Current Fuels Used for Cooking in China and India

Fuel	Fuels Used for Cooking* China (%)	India (%)
Liquefied Petroleum Gas	31.10	25.20
Coal	28.90	1.90
Biomass	26.70	57.90
Electricity	10.60	0.40
Kerosene	0.30	3.20
Dung	0.00	10.60
All other Fuels	2.40	0.40
Total	***100.00***	***100.00***

Source: **China**: Dalberg 2014, NBS China 2008; **India**: Dalberg 2013, Venkataraman et al. 2010.

*Percentages based on fraction of population using fuel for cooking.

Brief profiles for the primary cooking fuels used in India and China are provided below. Typical emission profiles at point of cooking fuel use were previously presented in Table ES-1 and Table ES-2. More details on the fuels themselves, including fuel heating values and stove thermal efficiencies by cooking fuel type, are presented in Section 2.2, while the fuel mix scenarios are described in Section 1.2.6.

India Electricity Grid: A breakdown of fuels contributing to India's national grid mix is depicted in Table 1-2. As of 2012, coal-fired electricity generation constitutes the majority of India's electrical grid at over 70% (Table 1-2). Hydropower and gas each comprise approximately 10% of the grid. Indian power plants together consume approximately 530 million metric tons (tonnes) of coal per year. Indian distribution losses are high at approximately 37% of generation. Distribution losses refer to the loss of electricity in the grid, which occurs between the generating plant and the point of consumption.

Table 1-2. Current Electricity Grid Mix in India

Production Type	2011 Electricity Production* India (%)
Coal and Peat	71.10
Hydroelectric	11.20
Natural Gas	8.30
Nuclear	2.90
Wind	2.50
Oil	2.00
Biomass	1.70
Solar Photovoltaic	0.20
Waste	0.09
Total Production	**100.00**
Distribution Losses*	***37.00%***

Source: International Energy Agency (IEA) 2012.

*Percentages based on total Gigawatt hours electricity produced from each fuel.

**Calculation: (DS-FC)/DS x 100, where DS = domestic supply and FC = final consumption.

China Electricity Grid: The composition of the Chinese electricity fuel mix as of 2011 is listed in Table 1-3. The electricity generation in China is comprised of nearly 80% coal and peat with hydroelectric following at approximately 15% (Table 1-3). The remaining five percent of China's electricity grid is generated from a mix of natural gas, nuclear, oil, biomass, and renewables. Chinese power plants annually consume a total of about 2 billion tonnes combined of bituminous coal (84%) and coke oven gas (10%), with less significant amounts of coking coal and blast furnace gas. Distribution losses in the Chinese system amount to 22% of generated electricity.

Table 1-3. Current Electricity Grid for China

Production Type	2011 Electricity Production* China (%)
Coal and Peat	79.00
Hydroelectric	14.80
Natural Gas	1.80
Nuclear	1.80
Wind	1.50
Biomass	0.70
Oil	0.20
Industrial Waste	0.20
Solar Photovoltaic	0.10
Total Production	**100.00**
Distribution Losses*	***22.00%***

Source: IEA 2011b.

*Percentages based on total Gigawatt hours electricity produced from each fuel.

**Calculation: (DS-FC)/DS x 100, where DS = domestic supply and FC = final consumption.

Liquefied Petroleum Gas is a clean burning gas, which is a co-product of the production of natural gas (NG) and crude oil (hereafter referred to as “LPG from oil”)) (GACC 2015). Both India and China currently use substantial quantities of LPG, with the fuel comprising 25% and 31% of each country’s current cooking fuel mix, respectively. Urban consumers have considerably better access to LPG than do their rural counterparts.

Coal is a black solid fossil fuel that is often used in countries where stoves serve a dual function of cooking and heating, such as China (GACC 2015). Twenty-nine percent of Chinese cooking is currently done with stoves using various coal products. The use of coal in India is much more limited, where it comprises only 1.9% of the current combustible fuel cooking mix. As mentioned above, coal is the predominant fuel used for electricity generation in both countries.

Biomass includes various types of plant-derived fuels and is one of the largest energy resources used for cooking in both China (26.7%) and India (57.9%). In China, a significant portion of biomass cooking fuel is agricultural residues (e.g., rice straw and husk) (Jingjing et al. 2001). The majority of biomass cooking fuel in India is manually gathered firewood (e.g., acacia, eucalyptus, sheesham, mango, etc.) (Singh et al. 2014a). Most biomass cooking fuel types (e.g., crop residues and firewood) currently used for cooking in India and China are unprocessed, with the exception of biomass pellets and charcoal from wood. For charcoal, small local markets in India carbonize wood in traditional earth mound kilns to increase the fuel’s energy density and ease of distribution (since charcoal is less bulky than the energy equivalent amount of firewood). Non-carbonized processed fuels like biomass pellets, a densified form of traditional biomass, are increasingly being used in developing countries.

Kerosene is a liquid product derived from crude oil. Kerosene is predominantly used for cooking in urban households where it causes a high number of accidents each year due to its flammability. Kerosene is used more widely in India, where it constitutes 3.2% of the current fuel mix, compared to China, where it is only 0.3% of all cooking fuel. None of the study scenarios anticipate expansion of kerosene use in coming years.

Dung, or animal waste, usually from cows, is used as an inexpensive fuel in rural areas. While dung represents a renewable energy source, burning solid dung inside may lead to high levels of harmful air emissions of particulate matter and volatile organic compounds (VOCs). Dung is sparingly used as a cooking fuel in China; however, as a result of its wide availability in rural India, dung accounts for 10.6% of total cooking fuel use in India. A number of the scenarios for India explore the effect on life cycle environmental impacts if dung use is replaced by alternative, cleaner burning fuels (Table 1-5).

Natural Gas is a gaseous clean burning fossil fuel that accounts for a small percentage of China’s current cooking fuel mix (2.4%). Piped natural gas is only available for urban customers with access, unlike LPG which can be distributed to rural communities in cylinders. None of the studied scenarios explore the potential expansion of natural gas use as a cooking fuel in either country because natural gas comprises only a small portion of the cooking fuel mix and its expansion is limited by accessibility issues. Inclusion of additional scenarios with expansion of piped natural gas for cooking will be evaluated in a future study that builds upon this study as discussed in Section 5.2.

Ethanol is a liquid fuel produced through the distillation of various agricultural products. Ethanol is not currently understood to be used as a cooking fuel in either China or India. The use of ethanol is explored in one of the study scenarios for India, due to the rapid expansion of global ethanol production and its high thermal efficiency when used as a cooking fuel.

DME is a gaseous fuel that is a product of the coal gasification process. DME does not currently comprise an appreciable portion of the cooking fuel mix in either country. The use of DME is considered in fuel use scenarios for China, as it is derived from coal, which is widely available in China, and the environmental, human health, and thermal performance of DME are improved compared to an energy-equivalent amount of coal. Because hard coal only makes up 1.9% of cooking fuel consumption in India, DME was not considered as a cooking fuel option for India.

1.2.5 System Boundary

This LCA focuses on a variety of current and potential future fuels for cookstoves in China and India, as detailed above in Table 1-1 and below in Table 1-5 and Table 1-8. The following life cycle stages are included for each fuel system:

- **Production** of the cookstove fuel feedstock, including all stages from extraction or acquisition of the fuel feedstock from nature through production into a form ready for processing into cooking fuel (e.g., cultivation and harvesting of sugarcane, extracting crude oil from wells).

- **Processing** of the fuel into a form ready to be used in a cookstove.

- **Distribution** of fuels from the production site to the processing location and on to a retail location or directly to the consumer. Distribution also includes bottling for fuels stored in cylinders (e.g., LPG).

- **Use** of the fuel via combustion of the fuel or use of electricity in a cookstove, including disposal of any combustion wastes or residues (e.g., ash).

Figure 1-1 provides the study boundaries for the baseline scenario for India and Figure 1-2 illustrates the study boundaries for the baseline scenario for China.

Fuel production and processing consists of all necessary steps, beginning at resource extraction, which are required to make the fuel ready for use in a cookstove. For ethanol produced from sugarcane, the fuel production stage includes impacts for growing and harvesting the sugarcane, while the processing stage includes the steps to convert the harvested cane into ethanol. Specific processing steps included in the analysis are described in greater detail for individual fuels in Section 2.2. In the case of electricity, power generation as well as transmission and distribution losses are incorporated in the system boundaries. Additionally, transportation requirements between all life cycle stages within the boundaries of this study are accounted for. Cookstove production and distribution, human energy expended during collection of fuels, and the production, preparation, consumption, and disposal of food and food wastes are outside the boundaries of this project. The rationale for excluding these stages is discussed in the next section (Section 1.2.5.1).

The use phase is modeled to reflect the combustion of the cooking fuels and fugitive emissions during use. The types and quantities of air emissions associated with fuel use depend on the fuel's elemental composition (e.g., average fixed carbon, ash content, and volatile matter) and the cookstove technology or technology mix (e.g., thermal efficiency) for each country, which affects the quantity of the fuel that must be consumed to deliver 1 GJ of cooking energy. At the fuel end-of-life, solid residues from the combustion of cookstove fuels (bottom ash and carbon char) are disposed. The major components of these wastes are determined by the type of fuel combusted, but biomass fuel combustion typically results in ash containing silica, alumina, calcium oxides, sodium, magnesium, and potassium. The disposal of these wastes is generally modeled assuming land application. In land application, the wastes in question are spread out over a landscape, often as an agricultural amendment, to ultimately be assimilated by the environment through physical, chemical, and biological processes.

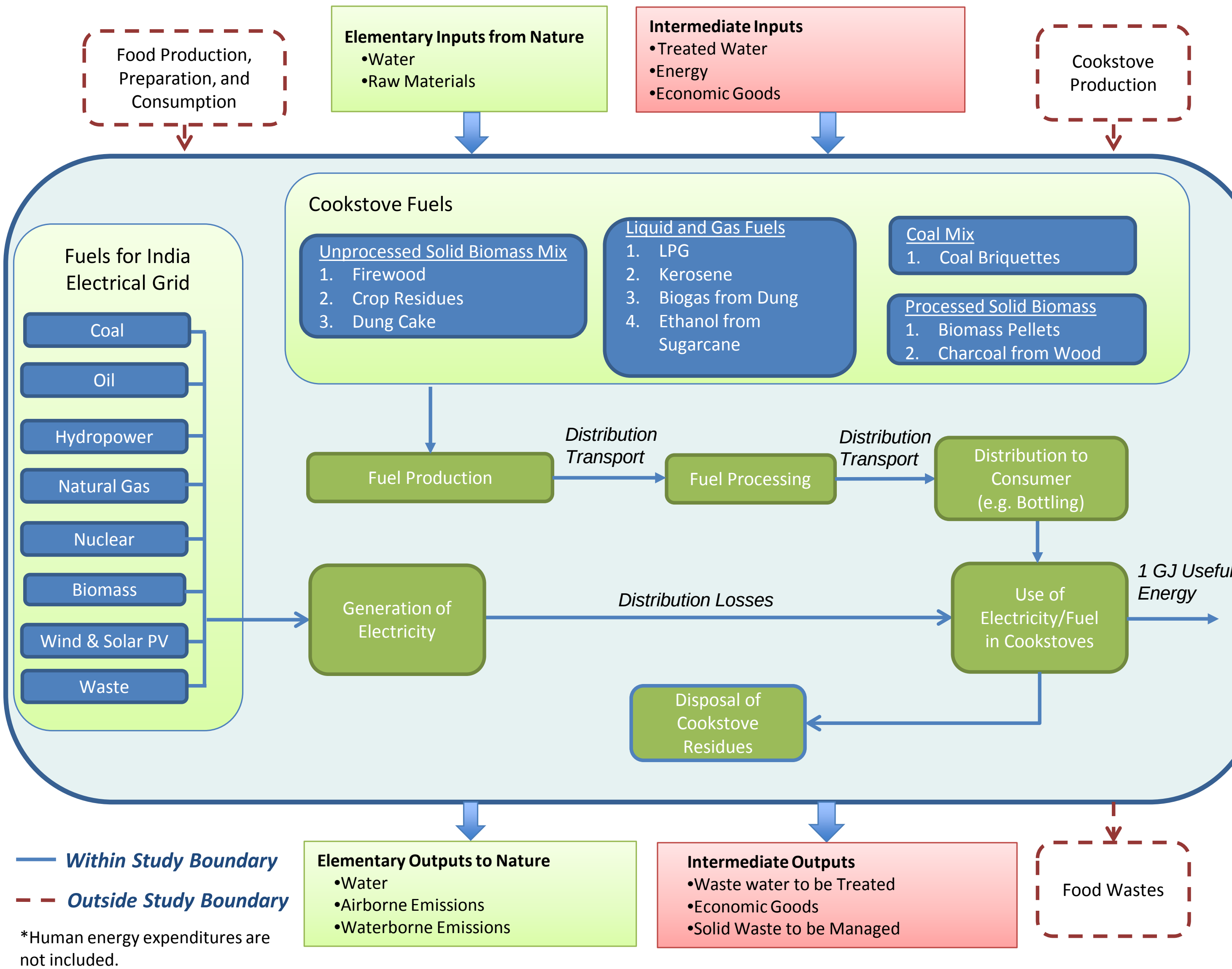


Figure 1-1. Study Boundaries of the Baseline Scenario for India

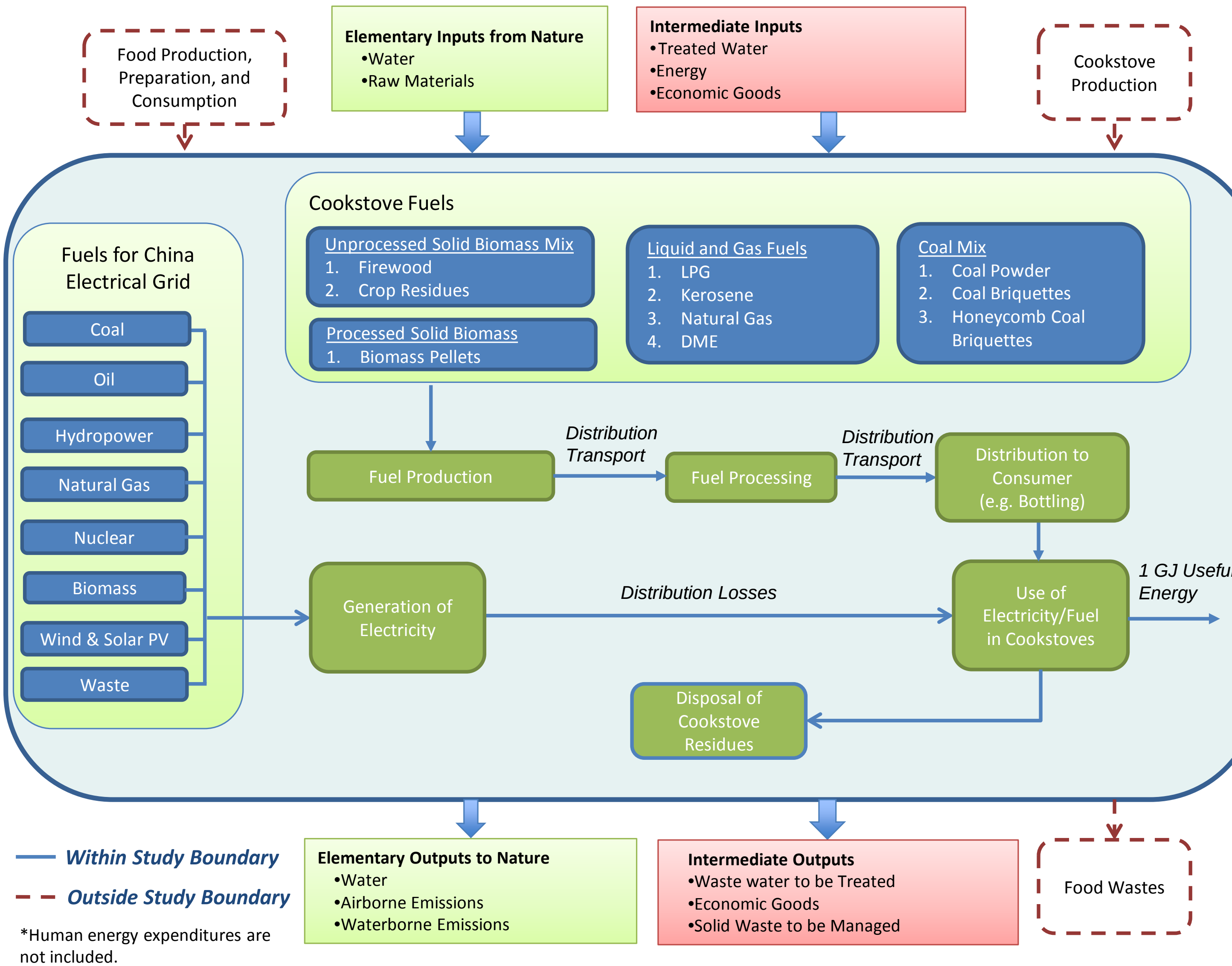


Figure 1-2. Study Boundaries of the Baseline Scenario for China

In addition to benchmarking the current fuel use for cookstoves in these two countries, a goal of this study is to consider scenarios for changes in the mix of cooking fuels used or changes in availability and utilization of cleaner burning fuels. Eight potential fuel mix scenarios affecting the life cycle environmental profile of cookstove fuel use in each country's market are evaluated. The details of these scenarios are described in Section 1.2.6.

1.2.5.1 System Components Excluded

The following components of each system are not included in this study.

Cookstove Production and Distribution. The focus of this study is the life cycle of fuels used within all types of cookstoves in the country; therefore, all burdens associated with production and distribution of the cookstoves themselves are excluded from the analysis. A previous LCA examining production of fuel-efficient cookstoves found that the use phase significantly dominates life cycle GHG emissions regardless of the combusted cooking fuel type utilized (Wilson 2016). Therefore, the overall life cycle impacts of the stove relative to the fuel are assumed to be negligible.

Human Energy Expended During the Collection or Use of Fuels. This analysis does not include human biological energy or emissions. Shifts in the mix of fuels may decrease the overall human energy and emissions expended during the distribution phase in some cases (e.g., shifting to fuels with higher energy density that are easier to transport, or that do not require consumer transport, such as electricity). Such affects would be associated with a high degree of uncertainty, and their benefits and burdens would be better captured by qualitative or analytical methods apart from LCA.

Food and Food Wastes. The focus of this study is the life cycle of fuels used to cook the food in the country; therefore, all burdens associated with production, preparation, storage, consumption, and disposal of the food being prepared using the fuels are excluded from the analysis.

Capital Equipment and Infrastructure. The energy and wastes associated with the manufacture of capital equipment and infrastructure are excluded from this analysis, including equipment to manufacture buildings, motor vehicles, and industrial machinery, as well as roads and electricity distribution infrastructure used to distribute fuels throughout the supply chain and to end users. In general, these types of capital equipment and infrastructure are used to produce and deliver large quantities of product output over a useful life of many years. Thus, energy and emissions associated with the production of these facilities and equipment generally become negligible when allocated over the total amount of output or service over their useful lives (Berglund 2006).

Stove Stacking. The transition from one cooking system to another does not always occur instantaneously. In communities that are undergoing transitions to a new cooking fuel type, field observations indicate that very often individual homes will initially use a mixture of new and traditional cooking systems. This phenomenon, known as 'stove-stacking,' allows households to take advantage of the differences that exist between the stove-fuel combinations that they employ. While this would ultimately affect the pace of change and the attendant shift in environmental impacts, it represents a dynamic force operating at a household level (Hiemstra-van der Horst and

Hovorka 2008) that lies outside of the study scope. This study focuses on scenarios encompassing the national cooking fuel mix, which could include households using a mixture of fuels, although this was not explicitly considered when developing the cooking fuel scenarios.

1.2.6 Scenario Development

As shown in Table 1-1, the baseline scenarios examine the most common fuels currently used for cooking in India and China. However, initiatives to decrease citizens’ exposure to indoor air pollution are encouraging use of cleaner burning fuels such as biomass pellets or liquid and gas fuels such as biogas, ethanol, and/or DME. Study scenarios were constructed based on insights derived from the literature, as well as common opinions and logic regarding fuels that have been traditionally considered to be “clean” or “dirty.” The goal in creating these scenarios is to propose reasonable scenarios that might be expected to yield environmental and human health benefits to facilitate analyzing the performance of these scenarios from a life cycle perspective.

Increases in cleaner fuels were set at reasonable amounts or based on the current urban or rural population that could possibly use the fuels in each country. No increases/decreases greater than 20% were considered for long-term changes to the use of cooking fuel. Such reasonable thresholds were set in the absence of detailed technological and economic feasibility studies centered on the practical potential of future fuel scenarios. This section provides an introduction to the current and potential future scenarios that are examined as a part of this analysis. Scenarios for each country are described separately in the following two sections.

Fuel choice depends on geographic location, market and technology access, and socio-economic parameters such as prosperity, education, and agro climatic conditions. Also, cooking habits and taste considerations influence fuel choice, generally towards more traditional fuels (Mainali et al. 2012). Access to some fuels may be limited, especially in remote rural areas. Conversely, access to unprocessed fuels like biomass and dung is more limited in urban areas. This includes access to electricity and LPG networks. LPG is distributed through pipelines in urban centers where infrastructure exists. Where pipelines do not exist, LPG cylinders are available. However, this fuel is less common in rural areas because of limited market access and high costs. Although electricity is a possible source of cooking energy, electric cookstoves are not primary fuel sources even in major cities (Mainali et al. 2012).

For each country and fuel source, the current average stove thermal efficiency per fuel type is applied to the analysis. For China, this constitutes a weighted average of traditional and improved stove efficiencies presented below in Table 1-9. A specific exploration of the benefits of increasing thermal efficiency within a fuel type is an area for future research, as the work considered within this study is focused on fuels. A more detailed analysis of the effect of stove efficiency on LCIA results will be evaluated in a future study.

1.2.6.1 India Cooking Fuels

Table 1-5 presents the baseline current mix of cookstove fuels used, as well as eight additional scenarios modeled in this LCA as potentially more sustainable cookstove fuel mixes that could be used within India. The name of each scenario is abbreviated to facilitate presentation and discussion of the results. The abbreviated names are presented in Table 1-4.

Table 1-4. Full and Abbreviated Scenario Names for India

Scenario	Brief Scenario Name	Full Scenario Name
	Current	Current Cookstove Fuel Use
(1)	Increase Urban Electric	Increase of Electrical Use in Urban
(2)	Increase Urban LPG	Increase of LPG in Urban
(3)	LPG Replaces Biomass	Increase in LPG/ Decrease in Biomass in both Urban and Rural
(4)	Increase Clean Electric	Cleaner Electrical Grid with Increase in Urban
(5)	LPG Replaces Rural Biomass	Increase in LPG/ Decrease in Biomass & Dung in Rural
(6)	Increase Biomass Pellets	Increased Biomass Pellets/Decreased Biomass & Dung
(7)	Ethanol Replaces Biomass	Increased Ethanol/Decreased Biomass & Dung
(8)	Biogas Replaces Biomass	Increased Biogas/Decreased Biomass & Dung

Table 1-5. Cooking Fuel Mix Scenarios Evaluated for India

Fuels:	Current	Increase Urban Electric	Increase Urban LPG	LPG Replaces Biomass	Increase Clean Electric	LPG Replaces Rural Biomass	Increase Biomass Pellets	Ethanol Replaces Biomass	Biogas Replaces Biomass
	Scenario	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Hard Coal	1.90%	1.90%	1.90%	1.90%	1.90%	1.90%	1.90%	1.90%	1.90%
LPG from Natural Gas*	5.29%	5.29%	7.39%	9.49%	5.29%	9.49%	5.29%	5.29%	5.29%
LPG from Crude Oil*	19.91%	19.91%	27.81%	35.71%	19.91%	35.71%	19.91%	19.91%	19.91%
Kerosene	3.20%	3.20%	3.20%	3.20%	3.20%	3.20%	3.20%	3.20%	3.20%
Electricity	0.40%	10.40%	0.40%	0.40%	10.40%	0.40%	0.40%	0.40%	0.40%
Sugarcane Ethanol	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	0.00%
Biogas from Cattle Dung	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	10.40%
Charcoal from Wood	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%
Biomass Pellets	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%	0.00%	0.00%
Firewood	49.00%	40.72%	40.72%	32.22%	40.72%	36.47%	44.97%	44.97%	44.97%
Crop Residue	8.90%	7.19%	7.19%	5.69%	7.19%	6.44%	7.94%	7.94%	7.94%
Dung Cake	10.60%	10.60%	10.60%	10.60%	10.60%	5.60%	5.60%	5.60%	5.60%
TOTAL	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

* LPG split between natural gas and crude oil based on statistics from the Government of India Ministry of Petroleum and Natural Gas Economics and Statistics Division 2014.

Current Baseline Scenario

The current baseline scenario for India is based on 2014 data from the Alliance as presented previously in Table 1-1. Approximately 70% of India's nearly 1.3 billion people lived in rural areas in 2010, while the remaining 30% lived in urban areas (World Bank 2014). Nearly 70% of these people, mostly those in rural areas, still rely on solid fuel feedstock for their cooking needs, with their attendant human and environmental impacts. The current fuel mix in India is dominated by the use of biomass, which constitutes 58% of all fuels used. It is assumed that 49% of this 58% is firewood while the remaining 8.9% consists of crop residue. Dung and coal complete the sources of solid fuel providing 10.6% and 2.3% of the fuel mix, respectively. LPG is also used extensively at the national level, at just over 25% of households. Kerosene is used in much more limited quantities (3.2% of the fuel mix). Unlike China, electricity is only very sparsely used for cooking in India.

Potential Future Scenarios

A variety of social and environmental issues have spurred interest in shifting the composition of the national cooking fuel mix in India. The emission of GHGs from direct combustion of fuels in household stoves can be significant due to the large percentage of the population engaging in such activities and the lack of any form of emission controls on residential cookstoves. Emissions of particulate matter have a particularly detrimental effect on human health. For these and additional reasons, including the significant amount of time required for rural individuals, mainly women, to gather firewood or dung, this research proposes eight scenarios that explore the benefits and burdens associated with a variety of shifts in the cooking fuel mixture.

Greater reliance on electricity is explored as it moves combustion out of the home, thereby decreasing human health impacts at the point-of-use. Increased use of LPG is explored due to its high stove thermal efficiencies, clean emissions profile, and user convenience (Dalberg 2013). Biomass pellets provide an attractive option as they leverage existing resources in a more efficient manner. Biogas also offers the opportunity to utilize an existing resource, dung, more effectively by boosting cookstove thermal efficiency. Sugarcane ethanol as a cooking fuel is explored due to the industries presence in India and interest on the part of the government to expand production (Tsiropolous et al. 2014). A move towards higher stove efficiencies is common to the majority of study scenarios. Stoves with higher thermal efficiencies not only require less fuel to deliver the same amount of useful cooking energy, but also often produce fewer undesirable products of incomplete combustion. Table 1-6 displays the average thermal efficiencies modeled for the stoves used for various cooking fuels for the Indian context. The study scenarios for India are outlined above in Table 1-5 and are described below.

1. **Increase Urban Electric:** This scenario explores the effects of increasing the use of electricity as a cooking fuel. The use of electricity is assumed to increase from its current level of 0.4% to a high of 10.4%. The use of both firewood and crop residue are decreased to adjust for the additional electricity use. Firewood use decreases by a little over eight percent of the total fuel mix while the share of crop residue in the fuel mixture decreases by 1.71%. In this scenario the composition of the fuel mix that is used to generate electricity stays consistent with that in the current scenario (Table 1-2). Electric stoves are assumed to have the highest thermal efficiency of any of the cookstoves considered.

2. **Increase Urban LPG:** In this scenario the use of LPG is increased from 25.2% to 35.2% of the national cooking fuel mix. The majority of the additional LPG is modeled as produced from crude oil (79%), while the remainder is produced from natural gas. Traditional sources of biomass, firewood and crop residue, are reduced corresponding to the increase in LPG.

3. **LPG Replaces Biomass:** This scenario proposes an even more dramatic increase in the use of LPG, to supply 45.2% of India's cooking energy needs. The share of biomass fuels (firewood and crop residues) in the fuel mix is decreased to approximately 38%.

4. **Increase Clean Electric:** This scenario is the same as the baseline electric scenario except that the scenario assumes that a cleaner electricity grid mix is used. The details of the cleaner grid are presented in Table 2-3.

5. **LPG Replaces Rural Biomass:** As in the previous scenario (3), LPG use is increased to 45.2% of the cookstove fuel mix. In this scenario a share of the displaced demand comes from dung, which is reduced to 5.6% of the fuel mix. Firewood accounts for 36% of the fuel mix. Crop residue is decreased from a high of 8.9% in the current scenario to 6.44% in this scenario.

6. **Increase Biomass Pellets:** This scenario targets the increased thermal efficiency of biomass when it is utilized in pelletized form. Pelletized biomass increases from zero to 10% of the Indian cooking fuel market. Traditional firewood, crop residue, and dung cake are all displaced by the increased use of pelletized biomass.

7. **Ethanol Replaces Biomass:** This scenario introduces the use of ethanol as a cooking fuel within the Indian context. In this scenario, ethanol distilled from sugarcane is assumed to provide energy for 10% of India's cooking needs. The use of dung is decreased by nearly half. Reduced use of firewood represents the remainder of displaced demand.

8. **Biogas Replaces Biomass:** The final scenario introduces the use of biogas which is produced in anaerobic digesters using animal dung as a feedstock. Biogas use increases from 0.4% of the fuel mix to 10.4% in this scenario. As in the previous scenario, the increase in biogas displaces use of solid dung and firewood.

Table 1-6. Thermal Efficiencies Modeled for Indian Cookstoves

Fuels:	Stove Thermal Efficiency	Source
Hard Coal	15.50%	Singh et al. 2014a
LPG from NG	57.00%	
LPG from Oil	57.00%	
Kerosene	47.00%	
Electricity	67.00%	Berick 2006
Sugarcane Ethanol	53.00%	MacCarty 2009
Biogas from Cattle Dung	55.00%	Singh et al. 2014a

Table 1-6. Thermal Efficiencies Modeled for Indian Cookstoves

Fuels:	**Stove Thermal Efficiency**	**Source**
Charcoal from Wood	17.50%	Singh et al. 2014a
Biomass Pellets	53.00%	Jetter et al. 2012
Firewood	13.50%	Singh et al. 2014a
Crop Residue	11.00%	
Dung Cake	8.50%	

Note: Stove thermal efficiencies modeled are based on the average mix of stove technologies currently in use in India and are not representative of specific stoves.

1.2.6.2 China Cooking Fuels

Table 1-8 presents the baseline current mix of cookstove fuels used, as well as eight additional scenarios modeled in this LCA as potentially more sustainable cookstove fuel mixes that could be used within China. The rationale for the scenario fuel mixes is described in the Potential Futures Scenarios subsection. The name of each scenario has been abbreviated to facilitate presentation and discussion of the results. The abbreviated names are presented in Table 1-7.

Table 1-7. Full and Abbreviated Scenario Names for China

Scenario	**Brief Scenario Name**	**Full Scenario Name**
	Current	Current Cookstove Fuel Use
(1)	Increase Electric	Increase of Electrical Use in Urban
(2)	LPG Replaces Biomass	Increase in LPG/ Decrease in Biomass in both Urban and Rural
(3)	LPG Replaces Coal	Increase in LPG/ Decrease in Coal in Rural
(4)	Increase Clean Electric	Cleaner Electrical Grid with Increase in Urban
(5)	Increase Biomass Pellets	Increase Biomass Pellets/ Decrease Biomass & Coal
(6)	Increase DME	Increase DME/ Decrease Biomass & Coal
(7)	Coal Swap	Increase Coal Briquettes/ Decrease Coal Powder
(8)	Ag Replaces Wood	Increase Agricultural (Ag) Residues/ Decrease Fuel & Brush Wood

Table 1-8. Cooking Fuel Mix Scenarios Evaluated for China

Fuels:	**Current**	**Increase Electric**	**LPG Replaces Biomass**	**LPG Replaces Coal**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Replaces Wood**
	Scenario	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Coal Mix	28.90%	8.90%	28.90%	8.90%	8.90%	18.90%	18.90%	28.90%	28.90%
Biomass Mix	26.70%	26.70%	6.70%	26.70%	26.70%	16.70%	16.70%	26.70%	26.70%
LPG	31.10%	31.10%	51.10%	51.10%	31.10%	31.10%	31.10%	31.10%	31.10%
Kerosene	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%
Electricity	10.60%	30.60%	10.60%	10.60%	30.60%	10.60%	10.60%	10.60%	10.60%
Natural Gas	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%
Biomass Pellets	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%	0.00%
DME	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	0.00%
TOTAL	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*

Current Baseline Scenario

The current fuel mix scenario for China is based on 2014 data from the Alliance as presented previously in Table 1-1. Approximately 47% of China's 1.4 billion people lived in rural areas in 2013, and the remaining 53% lived in urban areas (NBS China 2008). More than half of these people, mostly those in rural areas, still rely on solid fuel feedstock for their cooking needs, with their attendant human and environmental impacts. The current fuel mix in China is dominated by the use of three fuels: LPG, coal, and biomass. Each of these fuels comprise slightly less than one third of total fuel use. Nearly 11% of the population uses electricity as a cooking fuel. Small percentages of the population use kerosene or natural gas.

Potential Future Scenarios

A variety of social and environmental reasons exist for shifting the composition of national cooking fuel mixes in China. The emission of GHGs from direct combustion of fuels in household stoves can be significant due to the large percentage of the population engaging in such activities and the lack of any form of emission controls on residential cookstoves. Lack of emission controls on cookstoves also contributes to the exposure of individuals in the home to particulate matter, which is detrimental to both human and environmental health. For these and additional reasons, including the significant amount of time that rural individuals, mainly women, spend gathering biomass or dung, this research proposes eight scenarios that explore the benefits and burdens associated with a variety of shifts in the cooking fuel mixture.

Greater reliance on electricity is explored as it moves combustion out of the home, thereby decreasing human health impacts at the point-of-use. Increased use of LPG is explored due to its high stove thermal efficiencies, clean emissions profile, and user convenience (Dalberg 2013). Biomass pellets provide an attractive option as they leverage existing resources in a more efficient manner. Similarly, the increased use and production of coal briquettes allows the Chinese to continue utilizing their extensive coal resources in a way that is more efficient and protective of human health (Zhang et al. 2000). DME also leverages China's coal supplies. DME production has been expanding rapidly in recent years (Yang and Jackson 2012), and it provides the opportunity to produce electricity as a by-product (Larson 2004). A move towards higher stove efficiencies is common to the majority of study scenarios. Table 1-9 depicts the traditional and improved thermal efficiencies modeled for the stoves used for various cooking fuels for the Chinese context. The study scenarios, illustrated in Table 1-8, are described below.

1. **Increase Electric:** This scenario explores the effects of increasing the use of electricity as a cooking fuel. The use of electricity is assumed to increase from its current level of 10.6% to a high of 30.6%. Coal use is assumed to decrease by a corresponding amount, while the rest of the fuels stay fixed at the levels present in the baseline scenario. In this scenario the composition of the fuel mix that is used to generate electricity stays consistent with the composition in the current fuel mix scenario.

2. **LPG Replaces Biomass:** This scenario also proposes an increase in the use of LPG, however instead of replacing coal, LPG is used in place of solid biomass fuels. A portion of this replacement is assumed to happen in both rural and urban locations.

3. **LPG Replaces Coal:** The impacts of increasing the use of LPG by 20% are explored in this scenario. The level of LPG use is assumed to increase from 31.1% to 51.1% as a fraction of the fuel mix. The shift in LPG use acts as a substitute for coal in the current scenario, which decreases from 28.9% to 8.9% of the fuel mix.

4. **Increase Clean Electric:** Like scenario (1), this scenario proposes a 20% increase in the use of electricity as a cooking fuel. Again, the increased use of electricity is assumed to replace the burning of solid coal. The only difference between the scenarios is that the increased electricity use in this scenario is modeled based on a cleaner grid mix. A detailed comparison of the current and cleaner grid mix for China is presented in Chapter 2 (Table 2-4).

5. **Increase Biomass Pellets:** This scenario leverages the increased thermal efficiency that is realized when traditional biomass sources are converted into a pelletized form (Table 1-9). Pelletized biomass is assumed to compose 20% of the cooking fuel mix in this scenario. The use of both non-pelletized biomass and coal is each decreased by 10% each (in the total fuel mix).

6. **Increase DME:** The use of DME is increased from a low of zero percent in the current fuel mixture to a high of 20% in this scenario. As in scenario (5), the increase substitutes for equal shares of traditional biomass and coal use.

7. **Coal Swap:** This scenario explores the environmental effect of changing the form of a fuel rather than substituting a different fuel. As shown in Table 1-9, a cookstove is able to extract much more useful energy from a given quantity of coal when it is consumed in briquettes versus a powdered form. Because the form of coal used (e.g., powder, briquette, honeycomb briquette) is not specified in Table 1-8, the percent breakdown by fuels remains the same for the baseline scenario and scenario (7); however, results for the two scenarios (presented in Chapter 4) show differences related to the change in the form of coal used.

8. **Ag Replaces Wood:** In this scenario one form of biomass, agricultural residues, is substituted for another, fuel and brush wood. The total amount of biomass in the fuel mixture remains constant however. Unlike other scenarios where the increased fuel is used in a stove with higher efficiency, the increased use of agricultural residues to replace fuel wood leads to a decrease in stove thermal efficiency.

Table 1-9. Thermal Efficiencies Modeled for Chinese Cookstoves

Fuels:	Stove Thermal Efficiency		Source
	Traditional	Improved	
Coal Mix	22.3%	23.3%	Zhang et al. 2000
Coal Powder	14.3%	17.3%	
Coal Briquettes	37.1%	27.2%	
Honeycomb Coal Briquettes	23.4%	31.4%	
Biomass Mix	15.2%	16.7%	
Fuel & Brush Wood	19.2%	16.3%	
Ag Residues	10.3%	17.2%	
LPG	45.2%	42.1%	
Kerosene	44.8%	45.9%	Singh et al. 2014a
Electricity	67.0%		Barick 2006
Natural Gas	53.7%	60.9%	Zhang et al. 2000
Biomass Pellets	53.0%		Jetter et al. 2012
DME*	46.0%		Zhang et al. 2000

*Coal gas stove efficiency is used as a proxy for DME stove efficiency. Note: Stove thermal efficiencies modeled are based on the average mix of stove technologies currently in use in China and are generally not representative of specific stoves.

1.2.7 Data Sources Summary

The majority of LCI data were extracted from existing studies in publicly available academic literature. Table A-3 through Table A-72 in Appendix A contain detailed LCI inventory data for the life cycle stages modeled for each fuel system. Each table cites the sources for the data used. The data were constructed and data quality was scored according to the procedures established in the project Quality Assurance Project Plan (QAPP) *"Quality Assurance Project Plan for Comparative Life Cycle Assessment of Cooking Fuel Options in China and India"*, approved August 25, 2014.

1.2.8 Data Requirements

ISO standards 14040 and 14044 detail various aspects of data quality and data quality analysis. These ISO Standards state: "descriptions of data quality are important to understand the reliability of the study results and properly interpret the outcome of the study (ISO 2010a, 2010b)." These ISO Standards list three critical data quality criteria: time-related coverage, geographical coverage, and technology coverage. The following subsections discuss these three critical data quality criteria and the typical specifications associated with high quality data. Appendix A, Table A-2, adapted from Weidema and Wesnaes (1996), discusses all data quality criteria evaluated (the three critical criteria identified by the ISO Standards along with additional criteria identified by U.S. EPA).

The geographic scope of this study is fuel used in China or India, However, some fuels or upstream inputs to fuel production/processing are imported from other regions of the world. High quality data and information for geography-dependent processes (e.g., energy production) were obtained from country-specific articles and databases. Data for technology-based processes are based on the most recent average country-specific technology mix (e.g., the current production methods China employs for mining and processing coal). It is more difficult to evaluate data quality for future technologies not yet in use or that currently have a small market share. When more specific information was not available, data quality for future technological processes was based on current technological processes used in the same country. For example, for a scenario with increased use of natural gas to produce electricity in China, the future natural gas production is modeled assuming China will produce natural gas in the future using the same methods it currently employs.

High quality temporal data are typically temporal data that are less than six years from the reference year (2013 for this project), with the highest quality temporal data less than three years from the reference year. A difference of six years meets the top two data scores for temporal correlation as identified in Appendix A (Table A-2). In some cases, this goal was met, while in many cases the available data sources do not meet the temporal data quality goals. Projected scenarios are modeled with the same temporal parameters (e.g., electricity grid fuel mix) as scenarios that exist in today's operating landscape. In this way, differences in environmental results for fuel mix scenarios are focused on material and process differences for the fuels (and associated stove efficiencies) rather than influence from other factors not directly related to the change in fuel mix.

The data quality scores assigned to each unit process are recorded in Table A-4 through Table A-72.

1.2.9 Life Cycle Impact Assessment Methodology and Impact Categories

The full inventory of atmospheric and waterborne emissions generated in an LCA study is lengthy and diverse, making it difficult to interpret system differences in individual emissions in a concise and meaningful manner. Life Cycle Impact Assessment helps with interpretation of the emissions inventory. LCIA is defined in ISO 14044 Section 3.4 as the "phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (ISO 2010b)." In the LCIA phase, the inventory of emissions is first classified into categories in which the emissions may contribute to impacts on human health or the environment. Within each impact category, the emissions are then normalized to a common reporting basis, using characterization factors that express the impact of each substance relative to a reference substance.

Characterization factors have been defined to quantify the impact potential of LCI results. There are two main methods to developing LCIA characterization factors. The 'midpoint' method links LCI results to categories of commonly defined environmental concerns like eutrophication potential and global climate change potential. The 'endpoint' method further models the causality chain of environmental stressors to link LCI results to environmental damages (e.g., final impacts to human and ecosystem health). ISO standards allow the use of either method in the LCIA characterization step. Overall, indicators closer to the inventory result (midpoint indicators) have a higher level of scientific consensus, as less of the environmental mechanism is modeled. Conversely, endpoint and damage-oriented characterization models inevitably include more aggregation, or more assumptions (e.g., about fate and transport, exposures/ingestion, etc.). To reduce uncertainty in communication of results, this LCA focuses on indicators at the midpoint level.

1.2.9.1 Scope of Impact Assessment

This study addresses global, regional, and local impact categories of relevance to the cookstove sector, such as air emissions leading to human health issues, energy demand driving depletion of bio-based and fossil-fuel-resources, and GHG and BC emissions causing both short-term and long-term climate effects. For most of the impact categories examined, the ReCiPe impact assessment method is utilized to represent global conditions (Goedkoop et al. 2008). Characterization factors, which are developed on the basis of established impact pathways, form the basis of impact assessment methods such as ReCiPe. An impact pathway is a series of quantifiable relationships that can be used to link LCI emissions to units of environmental impact (e.g. kg CO_2-eq for GCCP). Characterization factors in ReCiPe were originally developed for global or European conditions and are not specific to China or India. Currently, no established LCIA method exists for the China or India scope. For the category of GCCP, a global impact, contributing elementary flows are characterized using factors reported by the Intergovernmental Panel on Climate Change (IPCC) in 2013 with a 100 year time horizon (IPCC 2013). Considerations for biogenic carbon accounting are covered in Section 2.4 and Section 2.5. BC and co-emitted species are characterized to BC – equivalents (eq) based on a novel method recently released by the Gold Standard Foundation (GSF) (GSF 2015). A detailed discussion of the BC methodology is presented in Section 2.6. In addition, some inventory results are incorporated in the results reported in the analysis as:

- Cumulative energy demand: this indicator is not an impact assessment, but rather is a cumulative inventory of non-renewable energy extracted and renewable energy utilized. The energy demand includes processing energy, transportation energy, and feedstock energy.

- Water depletion: this indicator is not an impact and is assessed only as an inventory item. It represents consumptive use of water.

A summary of the LCI and LCIA categories and methods used in this study are presented in Table 1-10. While this study focuses on environmental impacts and does not include impact categories which focus exclusively on human health, a number of included emission types are closely associated with both environmental and human health impacts. These include emissions leading to black carbon, particulate matter formation, and photochemical oxidant formation, all of which can lead to eye irritation, respiratory disease, increased risks of infection, and cancer. Linking these emissions definitively to human health impacts would introduce a higher level of uncertainty to the study results. Human health impacts are dependent not only on emission quantities, but also on the fate and transport of the emitted substances and the concentrations and pathways by which organisms are exposed to these substances. These detailed types of exposure information are not tracked in an LCI, requiring additional assumptions about the environmental mechanism to be made by the developer of the LCIA methodology. So while human health impacts are not explicitly estimated by this study, pertinent impact categories related to known human health impacts of cookstove use are included in the analysis. The results of this study could inform a more detailed assessment of the human health impacts from exposure to direct or indirect emissions from the cookstove fuel life cycle.

Table 1-10. Environmental Impact Category Descriptions and Units

Impact/Inventory Category	Description	Unit
Global Climate Change Potential	The global climate change potential impact category represents the heat trapping capacity of GHGs over a 100 year time horizon. All GHGs are characterized as kg CO_2 equivalents according to the IPCC 2013 5th Assessment Report global warming potentials.	kg CO_2 eq
Cumulative Energy Demand	The cumulative energy demand indicator accounts for the total usage of non-renewable fuels (natural gas, petroleum, coal, and nuclear) and renewable fuels (such as biomass and hydro). Energy is tracked based on the heating value of the fuel utilized from point of extraction, with all energy values summed together and reported on a MJ basis.	MJ
Water Depletion	Water depletion results, in alignment with the ReCiPe impact assessment method, are based on the volume of fresh water inputs to the life cycle of the assessed fuels. Water may be used in the product, evaporated or returned to the same or different water body or to land. If the water is returned to the same water body, it is assumed the water is returned at a degraded quality. Water consumption includes evaporative losses from establishment of hydroelectric dams.	m^3
Black Carbon and Short-Lived Climate Pollutants	BC, formed by incomplete combustion of fossil and bio-based fuels, is the carbon component of particulate matter (PM) 2.5 that most strongly absorbs light and thus has potential short-term (e.g., 20-year) radiative forcing effects (e.g., potential to contribute to climate warming). Organic carbon (OC) is also a carbon component of PM and possesses light-scattering properties typically resulting in climate cooling effects. PM from the cookstove sector is typically released with criteria pollutants, such as carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur oxides (SO_x), which may result in additional warming impacts or exert a cooling effect on climate. This indicator characterizes all PM and co-emitted pollutants to BC equivalents depending on the relative magnitude of short-term warming or cooling impacts. The BC method is based on the novel GSF method (GSF 2015).	kg BC eq
Particulate Matter Formation Potential	Particulate matter formation results in many negative health impacts such as effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. Primary pollutants (including PM2.5) and secondary pollutants (e.g., SOx and NOx) leading to particulate matter formation are characterized here as kg PM10 eq based on the ReCiPe impact assessment method.	kg PM10 eq
Terrestrial Acidification Potential	Terrestrial acidification potential quantifies the acidifying effect of substances on their environment. Important emissions leading to terrestrial acidification include SO_2, NOx, and NH_3. Results are characterized as kg SO_2 eq according to the ReCiPe impact assessment method.	kg SO_2 eq
Freshwater Eutrophication Potential	Freshwater eutrophication assesses the potential impacts from excessive load of macro-nutrients to the environment and eventual deposition in freshwater. Pollutants covered in this category are all P based (e.g. phosphate, phosphoric acid, phosphorus), with results characterized as kg P eq based on the ReCiPe impact assessment method.	kg P eq

Table 1-10. Environmental Impact Category Descriptions and Units

Impact/Inventory Category	Description	Unit
Photochemical Oxidant (Smog) Formation	The photochemical oxidant formation (e.g. smog formation) potential results determine the formation of reactive substances that cause harm to human health and vegetation. Results are characterized here to kg of NMVOC eq according to the ReCiPe impact assessment method. Some key emissions leading to photochemical oxidant formation include CO, methane (CH_4), NOx, NMVOCs, and SOx.	kg NMVOC
Ozone Depletion Potential	Measures stratospheric ozone depletion. Important contributing emissions include CFC compounds and halons. It is likely that ozone depletion is of lower importance for cookstoves fuels compared to other impact categories. There will be differences between stove options as fossil fuels generate ozone depleting emissions within their supply-chain that are absent in the biomass options. However, the ozone depletion category has become less critical following the regulation of the worst offending ozone depleting chemicals.	kg CFC-11 eq
Fossil Depletion	Fossil depletion captures the consumption of fossil fuels, primarily coal, natural gas, and crude oil. All fuels are normalized to kg oil eq based on the heating value of the fossil fuel and according to the ReCiPe impact assessment method.	kg oil eq

2. PROCESS DESCRIPTIONS AND METHODOLOGY

2.1 Overview

This section provides descriptions of fuel production for each cooking fuel analyzed for use in India and China. It also discusses the methodology used for allocations performed for a number of fuels in this analysis. Discussions of the impact assessment considerations for biogenic carbon accounting, non-renewable forestry calculations and the BC indicator are also provided. Finally, a high level discussion of the model framework built for this project is provided at the end of this section.

2.2 Life Cycle Inventory Data for Current and Potential Fuels Used in India and China

No new unit process datasets were produced for this LCA analysis. LCI unit process data were either acquired or adapted from publicly available sources. Table A-4 through Table A-72 in Appendix A provide detailed LCI values, data quality scores and citations for each value used in the modeling for each fuel. The level of granularity available for each cooking fuel type is dependent on the level of detail reported in the utilized literature sources. For India, cookstove modeling assumptions are largely based on work conducted by Singh and colleagues (2014) for all cookstove fuels except sugarcane ethanol and biomass pellets. Sugarcane ethanol production in India is derived from a study by Tsiropoulos and colleagues (2014), with combustion impacts calculated from laboratory tests by Aprevecho Research Center (Barick 2006, MacCarty 2009). For the Chinese cookstove fuels, fuel modeling data are primarily from work by Zhang and colleagues (2000). Combustion emissions of volatile organic compounds (VOCs) for Chinese fuels were further speculated based on research by Tsai et al. (2003). For both China and India, biomass pellet production is from work by Jungbluth and colleagues (2007a), while combustion of the pellets is modeled based on emission and stove efficiency profiles from Jetter, et al (2012). Documentation of the processed cookstove fuel heating values is provided in the next section, followed by a discussion on the supply chain for each fuel. Upstream processes such as transport and ancillary material inputs are modeled using information from the National Renewable Energy Laboratory's (NREL's) US Life Cycle Inventory (US LCI) Database and ecoinvent v2.2. The US LCI is a publicly available LCI source specific to US conditions (NREL 2012) and ecoinvent v2.2 is a private Swiss LCI database with data for many global unit processes (Ecoinvent Centre 2010). Where possible, these upstream databases are adapted to the geographic scope of interest, i.e., by linking process electricity requirements to the country-specific grid mix.

2.2.1 Processed Fuel Heating Values

The higher heating values (HHVs) employed in the LCA model for India and China are shown in Table 2-1 and Table 2-2, respectively. Associated cookstove thermal efficiencies for each country and fuel combination were previously provided in Table 1-6 and Table 1-9 for India and China, respectively.

Table 2-1. Heating Values of Cooking Fuels in India

Cooking Fuel Type	HHV (MJ/kg)	Source
Firewood	15.8	Singh et al. 2014a
Crop Residue	14.6	Singh et al. 2014a
Dung Cake	13.3	Singh et al. 2014a
Charcoal Briquettes from Wood	27.9	Singh et al. 2014a
Biomass Pellets	17.9	Singh et al. 2014a & Jetter et al. 2012
Ethanol from Sugarcane	28.3	MacCarty 2009
Biogas from Dung	18.2	Singh et al. 2014a
LPG	53.4	Singh et al. 2014a
Kerosene	49.0	Singh et al. 2014a
Hard Coal	16.3	Singh et al. 2014a

Table 2-2. Heating Values of Cooking Fuels in China

Cooking Fuel Type	HHV (MJ/kg)	Source
Firewood	15.3	Zhang et al 2000
Crop residue	14.0-14.5	Zhang et al 2000
Biomass Pellets	15.9	Jungbluth et al. 2007a
LPG	49.0	Zhang et al. 2000
Kerosene	49.0	Singh et al. 2014a
Natural Gas	51.3	Zhang et al. 2000
DME	28.4	Zhang et al. 2000
Hard Coal	13.9	Zhang et al. 2000

2.2.2 Electricity

The electricity mix is based on the average electricity mix from the IEA for India (2012) and for China (2011b). The electricity modules include estimates of distribution losses, which are substantial for both countries: 22% for China and 37% for India. The mix of fuels in the electrical grid is presented in Table 2-3 for India, and in Table 2-4 for China. These tables also provide the electrical grid fuel mix projections used to model a cleaner future electricity grid in each country. The cleaner electricity grid focuses on a decrease of coal use, which is currently used at a rate of over 70% to produce electricity in each country, while increasing cleaner fuels such as hydropower, nuclear, natural gas, photovoltaics (PV), and wind. The electric stove thermal efficiency modeled for both countries is 67% (Barick 2006).

Table 2-3. Current and Cleaner Electricity Grids for India

Fuels:	Current India Electrical Grid	Cleaner India Electrical Grid
Coal	71.07%	59.07%
Oil	2.01%	2.01%
Natural Gas	8.33%	14.33%
Biofuels	1.72%	1.72%
Nuclear	2.92%	4.92%
Hydro	11.16%	14.16%
Solar PV	0.19%	0.19%
Wind	2.51%	3.51%

Table 2-3. Current and Cleaner Electricity Grids for India

Fuels:	Current India Electrical Grid	Cleaner India Electrical Grid
Waste	0.09%	0.09%
TOTAL	100.00%	100.00%

Sources: IEA 2012.

Table 2-4. Current and Cleaner Electricity Grids for China

Fuels:	Current China Electrical Grid	Cleaner China Electrical Grid
Coal	79.0%	59.0%
Oil	0.20%	0.20%
Natural Gas	1.80%	7.80%
Biomass	0.70%	0.70%
Nuclear	1.80%	3.80%
Hydro	14.8%	24.8%
Solar PV	0.10%	0.10%
Wind	1.50%	3.50%
Waste	0.20%	0.20%
TOTAL	100.00%	100.00%

Source: IEA 2011b.

2.2.3 Liquefied Petroleum Gas

In India, 21% of LPG is assumed to be produced from natural gas and 79% from crude oil (MPNG 2014). For India LPG from NG, natural gas extraction is based on drilling, metering, testing and servicing of oil wells and production data of Oil and Natural Gas Corporation (ONGC), the largest oil company in India. Eighty-four percent of natural gas in India comes from offshore sources and 16% is from onshore sources. LPG production is based on the scenario of an LPG production line of ONGC Uran Gas fractionating plant located near Mumbai, India. Natural gas is transported to the gas fractionating plant by pipeline (500 km from onshore, 250 km from offshore). Processing requirements are allocated to the outputs from LPG production on a direct mass basis. The bottling stage is modeled based on the per-day production scenario of Indian Oil Corporation Limited (IOCL) Barkhola bottling plant located in Assam, India. This plant is one of the recent state-of-the art bottling plants commissioned by IOCL and is considered representative of bottling plants in India. LPG is bottled in steel cylinders (Singh et al 2014a). Incoming transport of natural gas to the bottling plant is 60% by rail (1000 km) and 40% by heavy duty vehicle (500 km). The bottled LPG is then transported 750 km by heavy duty diesel vehicle to the distributor and 100 km by light duty diesel vehicle from the distributor to retail.

For the 79% of LPG produced from crude oil, the India model considers only the domestic production of refined petroleum fuels. The exclusion of overseas crude oil is not expected to impact findings significantly because only the extraction stage is impacted (not the refining stage), and Indian companies engage in extraction of crude oil following globally accepted practices and operational standards –equivalent to overseas oil companies (Singh et al. 2014a). Onshore crude oil is 30% of refinery inputs, and is transported 1000 km by rail to the refinery; offshore crude oil makes up 70% of the inputs and is first transported 500 km to the port, then 60% is transported

1000 km by rail to refineries and 40% is transported 500 km to refineries by heavy duty diesel vehicle (Singh et al. 2014a). Mass allocation is used to partition petroleum refining burdens to different refinery products. Once the LPG reaches the bottling plant, the supply chain is equivalent to that modeled for the NG LPG supply chain.

LPG production for China is based on two Swiss refineries for the year 2000. Electricity grid mix and rail transport are adapted to the China geographic scope. The bottling stage is simulated based on the model created for India.

2.2.4 Kerosene

For the India kerosene model, only the domestic production of petroleum refining products is considered. The exclusion of overseas crude oil is not expected to impact findings significantly because only the extraction stage is affected (not the refining stage), and Indian companies engage in extraction of crude oil following globally accepted practices and operational standards equivalent to overseas oil companies. Onshore crude oil (30% of refinery inputs) is transported 1000 km by rail to the refinery; offshore crude oil (70% of the inputs) is first transported 500 km to the port, then 60% is transported 1000 km by rail to refineries and 40% is transported 500 km to refineries by heavy duty diesel vehicle. Mass allocation is used to partition petroleum refining burdens to different refinery products. Thirty percent of kerosene is assumed to be transported 1000 km by rail, while the remaining 70% travels the same distance by way of heavy duty diesel vehicle. All kerosene is transported in a light duty diesel vehicle 100 km from the distributor to retail. The kerosene pressure stove efficiency is 47%. Similar to LPG, the bottling stage is simulated based on the per-day production scenario of the IOCL Barkhola bottling plant located in Assam, India. Kerosene is bottled in steel cylinders (Singh et al. 2014a).

For China, production of petroleum products is adapted to the China geographic scope using a refinery dataset in ecoinvent (Ecoinvent Centre 2010). The data set includes all flows of materials and energy for throughput of one kilogram of crude oil in the refinery. The multi- output process 'crude oil, in refinery' delivers the co-products gasoline, bitumen, diesel, light fuel oil, heavy fuel oil, kerosene, naphtha, propane/ butane, refinery gas, secondary sulfur, and electricity. The impacts of processing are allocated to the different products on a mass basis. Electricity grid mix and rail transport are adapted to the China geographic scope. The bottling stage is simulated based on the per-day production scenario of the IOCL Barkhola bottling plant located in Assam, India. Kerosene is bottled in steel cylinders. Incoming transport to the bottling plant is 60% rail (1000 km) and 40% heavy duty vehicle (500 km). All bottled kerosene is modeled as being transported 750 km by heavy duty diesel vehicle to the distributor where it travels a further 100 km by light duty diesel vehicle from the distributor to retail. Kerosene is combusted in wick and pressure stoves.

2.2.5 Coal

In India, coal for cookstove use is modeled as produced in an open cast surface mine. Surface mines account for over 80% of total coal production in India, and almost 100% of the coal grades used for cooking. The consumption of coal for cooking is primarily in areas near coal mines, with an average transport distance of 100 km (rail). Coal is combusted in a metal stove. The coal ash remaining after combustion, as well as the mining overburden, is assumed to be disposed in landfills.

In China, coal is used in a variety of forms, including unprocessed, washed and dried, powdered, formed into briquettes, or formed into honeycomb briquettes. Coal is combusted in metal and brick stoves (both traditional and improved) which have efficiencies assumed to range from 14% - 37% depending on the fuel/stove technology combination (Zhang et al. 2000). The coal ash remaining after combustion, as well as the mining overburden, is assumed to be disposed in landfills. The process also includes estimated emissions due to leaching from coal heaps into groundwater at storage sites.

2.2.6 Firewood

Typical tree species used for firewood in India are acacia, eucalyptus, sheesham and mango. Forty-one percent of firewood cooking fuel in India is estimated to be non-renewable, based on trends in forest land area, renewable biomass generation on forest land, and demand for cooking firewood as discussed in Section 2.5 (FAO 2010, Drigo 2014). Firewood is assumed to be collected manually and combusted in a traditional mud stove. The remaining ash is modeled as land applied.

In China, cooking fuel wood is harvested from mature trees or large branches (e.g., eucalyptus, acacia, oak, pine, poplar, willows, etc.), obtained manually from local forest and sun-dried. Brush wood, or thin branches of brush which normally grow faster than trees, that is obtained locally is also assumed to be sun-dried and held in a large storage room for a minimum of four weeks prior to use. About 43% of firewood from China is estimated to be non-renewable, based on trends in forest area, renewable biomass generation on forest land, and demand for firewood for cooking. Fuel wood and brush wood are assumed to be collected manually and combusted in traditional and improved brick and metals stoves. The remaining ash is modeled as land applied.

2.2.7 Crop Residues

In India, residues from crops such as rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed, mustard, and groundnut are burned by households. Crop residues are modeled as manually collected, air dried but not further processed, and combusted in traditional mud stoves. In China, residues from maize, wheat, and rice are modeled as manually collected and combusted in traditional and improved brick and metal stoves. In both countries, the ash remaining after stove use is assumed to be land applied.

2.2.8 Biomass Pellets

For pellets, biomass species mixes are specific to each country. It is assumed that biomass species (85% firewood, 15% crop residues) typical for use in India are manually collected from local areas and pelletized via motorized machinery operated with electricity by small-scale manufacturers. Approximately 41% of the wood input (85% of total biomass pellet composition) is calculated to be non-renewable, which equates to approximately 35% of feedstock being non-renewable. Manual collection and small-scale mechanized pelletization are also assumed for China. In China, approximately 43% of the wood and brush inputs (56% of national biomass market mix) are estimated to be non-renewable, which equates to approximately 24% of feedstock being non-renewable. The processing energy and distribution transport are adapted from Austria and central Europe. Electricity is required for pelletization and is modeled using representative grids for the Indian and Chinese geographic scopes, respectively (IEA 2011b, 2012). Some incoming transport to pelletization (rail and truck) is included. The model for emissions from biomass pellet combustion is based on laboratory testing results.

2.2.9 Charcoal from Wood

In India, charcoal is produced from wood in a traditional earth mound kiln. The charcoal yield from the kiln is modeled as 30%, and the combustion residuals are land applied. As with other wood fuels in India, 41% of the wood the charcoal is derived from is assumed to be non-renewable. The firewood is assumed to be collected and brought to the charcoal kiln manually. Charcoal is modeled as combusted in a metal stove. Charcoal is an informal manufacturing sector in India, and it is assumed charcoal is used for cooking only by those living near charcoal kilns. No notable use of wood based charcoal was found for cooking in China (Singh et al. 2014a).

2.2.10 Dung

The dung of stall fed cattle and buffaloes is converted into dung cake primarily by women who mix the manually collected dung with residual feed (e.g., straw, wood chips). Dung cake is combusted in a traditional mud stove with a low thermal efficiency. The remaining ash after combustion is modeled as land applied. Dung cake is a significant fuel source for cooking only in India.

2.2.11 Ethanol

Ethanol production and processing is modeled based on the data provided by Tsiropoulos and colleagues (2014). In India, sugarcane cultivation practices are almost exclusively manual, with the exception of plowing, which is modeled as partially mechanized in some states. Pre- and post-harvest burning of straw is not practiced in most of India. Sugarcane is transported 12 km by truck to the sugarcane mill. The output products of the conventional sugar mill are sugar, molasses, and electricity from surplus bagasse. Conventional mills represent 75% of the sugar production in India. Bagasse provides all necessary energy requirements at the mill as well as surplus electricity, which is considered a useful co-product to replace grid electricity in India. Sugarcane ethanol is then produced from the molasses. This study considers a weighted average of ethanol distilleries as standalone distilleries and as adjacent to sugar refineries. Molasses is transported on average 75 km to the ethanol plant. Sugarcane ethanol production energy is also provided by bagasse. The model is based on a hydrous ethanol yield (for 95% ethanol by volume) of 84.7 liters/tonne of cane and an ethanol density of 0.789 kg/L. All ethanol is assumed to be transported 750 km by heavy duty vehicle to the distributor and 100 km by light duty vehicle from the distributor to retail. Sugarcane ethanol combustion emissions are based on laboratory testing, rather than field results (e.g., actual measurements from cookstoves in use within India). Sugarcane ethanol is not considered as a cooking fuel in China, as sugarcane production is less prevalent in China than it is in India based on Food and Agricultural Organization (FAO) statistics from 2012.

2.2.12 Biogas

This study considers a two cubic meter household type fixed dome anaerobic digester (AD) operating in continuous feeding mode for 350 days/year and 10 years operational life (UN 2007). The AD is loaded with 19.3 kg/day of fresh dung mixed with small quantities of water to produce 1.31 m^3/day of biogas (Singh et al. 2014a). Leakage is the source of fuel production emissions. Approximately one percent of biogas (methane) generated is assumed to leak from the system

(Afrane 2011, Borjesson 2006). Digested slurry is a useful co-product and is stored for application in land farming. The AD is located at the home where the fuel is used (distributed through piping running from the digester to the home).

2.2.13 Natural Gas

Natural gas extraction is based on Russian production data and long-distance pipeline transport of natural gas to China. Energy requirements for operation of the gas pipeline network are adapted from an Italian company data set in ecoinvent for delivery of natural gas to consumers via pipelines (Ecoinvent Centre 2010). The total leakage rate, modeled as 1.4% for long-distance pipeline transport, is based on European data (Ecoinvent Centre 2010). The electricity grid mix and rail transport are adapted to the China geographic scope. Piped natural gas is not a major cookstove fuel in India.

2.2.14 Dimethyl Ether

DME is modeled as produced from coal gas and delivered to rural China via a long-distance pipeline network followed by bottling close to end consumers (see Larson 2004 for description of DME production and distribution process). The process technology, coal gas produced from coke oven gas, is adapted from ecoinvent for the Chinese geographic scope. Transport of the coal gas from plant to rural consumer is via high pressure network. DME is assumed to be burned in a standard multiple-burner gas range; the combustion profile for this fuel/cookstove technology combination reflects use of only one burner, and is based on laboratory testing results. The fuel is available in bottles and remains in gaseous form under normal atmospheric conditions. DME is considered as a cooking fuel only for China, since coal (the fuel DME is derived from) is not widely used for cooking in China. While DME is not currently used as a cooking fuel type in China, the production technology is well understood (Larson 2004). Pursuit of DME as a cooking fuel in India is considered unlikely due to the current low prevalence of coal as heat source for cooking.

2.3 Allocation Methodology

For processes that produce more than one useful output, allocation is required. No single allocation method is suitable for every scenario. The method used for handling product allocation will vary from one system to another but the choice of allocation is not arbitrary. ISO 14044, Section 4.3.4.2 states that "the inventory is based on material balances between input and output. Allocation procedures should therefore approximate as much as possible such fundamental input/output relationships and characteristics (ISO 2010b)." In this analysis, the baseline method used for modeling multi-output product processes with one primary product and one or more unavoidable co-products is the "cut-off" approach. Under this approach, all burdens are assigned to the primary product. The cut-off method is outlined in detail in the 1993 EPA Life Cycle Assessment: Inventory Guidelines and Principles document (Baumann and Tillman 2004).

Processes in the cookstove fuel life cycle requiring allocation include crop residues and other products generating co-products. For instance, production of sugarcane ethanol may result in a net production of electricity from the combusted bagasse. For crop residues, burdens begin at collection of the biomass from the field; all cultivation burdens are assigned to the primary crop. For co-produced electricity from ethanol production, credits associated with exporting electricity are considered outside the system boundaries. The digested slurry from the biogas production in the AD may also be used as a fertilizer for supporting household crop production. The benefits realized from increased nutrients available from the land applied digested slurry are not captured in the impact assessment in this work. Multiple allocation methods exist and may have a significant influence on results. The Next Steps Section of this study (Section 5) describes potential allocation sensitivity analyses anticipated to be conducted for the above mentioned multi-output product systems in the next phase of the research.

2.4 Biogenic Carbon Accounting

In biomass fuel systems, CO_2 is removed from the atmosphere and incorporated into the plant material that is harvested from the forest or field. This (biogenic) carbon is stored in the material throughout the life of the product until that fuel is combusted or degrades, at which point the carbon is released back into the environment. Combustion and degradation releases are predominantly in the form of CO_2 and CH_4. This study, in alignment with the IPCC methodology, assumes a net zero impact for biogenic carbon that is removed from the atmosphere in the form of CO_2 and later returned to the atmosphere, e.g., as CO_2 emissions from the combustion of biomass cookstove fuels. That is, if the carbon removed from the atmosphere is returned to the atmosphere in the same form, the net impact GWP is zero. Impacts associated with the emission of biogenic carbon in the form of CH_4 are included since CH_4 was not removed from the atmosphere and its global warming potential (GWP) is 28 times that of CO_2 when applying the IPCC 2013 100a LCIA method. The one exception to this is the CO_2 emissions from non-renewable wood fuel in China and India associated with deforestation and, therefore, long-term reduction of global CO_2 sinks. The method used to calculate the non-renewable portion of wood for cooking fuel is described in the next section.

2.5 Non-Renewable Wood Fuel Calculations

In the GHG analysis, the carbon dioxide emissions for the portion of the biomass fuel from unsustainable use of wood fuel are considered non-renewable, and, therefore incorporated into the overall GCCP results. The calculations for the renewable and non-renewable supply of wood for cooking fuel use were based on a multi-step approach outlined by Singh and colleagues (2014). First, the biomass stock in m^3 for each country (from FAO 2010 Table 10) was multiplied by the regional factor for tonnes of above-ground biomass (AGB) per m^3 (from FAO 2010 Table 2.18) to calculate the tonnes of AGB. The amount of below-ground biomass (BGB) was calculated by multiplying the tonnes of AGB by the regional factor for BGB/AGB (from FAO 2010 Table 2.18). The amount of dead wood was then calculated using the regional factor for dead-to-live biomass ratio (from FAO 2010 Table 2.18) applied to the total AGB and BGB. Next, the average annual increase or decrease in forest land for each country was calculated based on the carbon stocks in living forest biomass reported for each country in 2000 and 2010 (from FAO 2010 Table 11). The annual firewood supply potential for each country was then calculated as the total weight of AGB and dead wood multiplied by country-specific factors for the percent accessibility to forests (from the Yale WISDOM Database (Drigo 2014)) and the country-specific average annual change in forest land.

The annual demand for firewood cooking fuel (tonnes) for each country was calculated based on the country-specific cooking energy demand per household multiplied by the number of households using wood for cooking fuel, divided by the cooking energy per kg of firewood (calculated as the lower heating value of firewood multiplied by stove efficiency). For India, 11.0 MJ of cooking energy are consumed per household per day (Habib et al. 2004), with 105 million rural households and 16 million urban households using wood for cooking fuel (Singh et al. 2014). In China, 13.6 MJ of cooking energy are consumed per household per day (Zhou et al. 2007), with over 131 million rural households and over nine million urban households using wood for cooking according to World Bank statistics. Finally, the renewable percentage of cooking firewood was calculated as the annual firewood supply potential divided by the total annual demand for cooking firewood. The percentage of annual firewood demand that cannot be met by the annual firewood supply potential was considered non-renewable.

2.6 Black Carbon and Short-Lived Climate Pollutants Calculations

This section summarizes key physical parameters considered in the approach to include the differences in potential amounts of BC, organic carbon (OC), and other co-emitted species produced from use of the investigated cookstove/fuel technologies. BC and co-emitted species are formed by combustion of fossil and bio-based fuels (e.g., diesel, coal, crop residues).

Per the Gold Standard Framework method (GSF 2015), fuel production, transport, and consumption life cycle phases are included in the inventory and impact assessment. An inventory of BC and OC is based on the quantity of particulate matter (less than or equal to 2.5 microns of aerodynamic diameter-PM2.5) released for each inventory step in the cookstove fuel/technology life cycle. In many cases, LCI data sources do not specify the type of PM emissions (e.g., outputs are reported as ‘particulate matter’ or ‘particulate matter, unspecified’). For upstream process inventories where PM emission speciation is not provided, no BC and/or OC emission factors are applied. However, co-emitted species emission factors for these processes are included. In the foreground cookstove fuel combustion, BC and OC emission factors based on quantity of PM released (e.g., per fraction reported as PM2.5) are applied. Where no size distinctions between PM emissions have been made in LCI data sources, all PM emissions from fuel combustion are assumed to be of the fine particle variety, e.g., of less than or equal to 2.5 microns in size.[1]

Carbon in PM2.5 emissions takes the following forms: 1) organic carbon; 2) Elemental carbon (EC), which usually includes soot; and 3) carbonate ion ($CO3^{-2}$). Methods which measure light absorption in PM2.5 assume that the light absorbing component is BC and partitioning of EC and OC is somewhat arbitrary. Though some components of OC may be light-absorbing (e.g., brown carbon or BrC), most researchers presume that OC possess light-scattering properties (e.g., producing climate cooling effects). Because there is high uncertainty and lack of consensus on the ratio BrC class of OC compounds for each fraction of OC, analyzing impacts of BrC in OC is excluded in this analysis and instead focus is placed on the EC or soot portion and the OC portions of the PM2.5 emissions. In other words, BC emissions may be estimated by assuming that only the EC portion of the PM2.5 emissions contributes to BC release and subsequent positive radiative forcing, while OC emissions are assumed to contribute to negative radiative forcing. This approach requires estimating the PM2.5 emission amount and source-specific EC-to-PM2.5 and then the BC-to-OC ratio for each of the fuel/stove technologies being investigated in the study.

[1] Per Bay Area Air Quality Management District (2008) “Secondary PM and combustion soot tend to be fine particles (PM 2.5), whereas fugitive dust is mostly coarse particles”.

Potential climate forcing impacts resulting from BC/OC and co-emitted species include direct, albedo, and other indirect effects. Overall, most estimates indicate BC yielding a net warming effect on climate but co-emitted species can have some offsetting effects, as discussed below. Species co-emitted with BC/OC such as carbon monoxide (CO), NMVOCs, nitrogen oxides (NOx), and sulfur dioxide (SO_2) are pre-cursors to the formation of sulfate and/or organic aerosols in the atmosphere. These aerosols affect reflectivity and other cloud properties and have a cooling affect.

BC and other short lived climate pollutants (SLCPs) such as the aforementioned co-emitted species are distinguished from other climate-forcing emissions (e.g., GHGs) in that their atmospheric lifetime is not as long-lived, so potential impacts are estimated on a shorter time-scale and can be very geographic and seasonally dependent (unlike long-lived, well-mixed GHGs). However, short-lived forcing effects of BC are substantial compared to effects of long-lived GHGs from the same sources, even when the forcing is integrated over 100 years. The GCCP of BC and co-emitted species included in this approach are calculated using GWP 20-year BC eq. factors from IPCC 2013 as summarized in Table 2-5.

Table 2-5. Characterization Factors for BC eq

	Included in GSF 2015	GWP(20) per IPCC 2013	BC eq
Warming Effects	BC	2421	1
	NOx	16.7	0.00690
	CO	5.9	0.002
	NMVOC	14	0.006
Cooling Effects	OC	-244	-0.1
	SO4 (-2)	-141	-0.058

Sources: IPCC 2013 and GSF 2015.

2.7 LCA Model Framework

All LCI unit processes developed for this work (summarized in Appendix A) were input into the US Federal LCA Digital Commons Life Cycle Inventory Unit Process Templates (in MS Excel format) (USDA and U.S. EPA 2015). To build the life cycle model, the unit processes were imported into the open-source OpenLCA software (Version 1.4.2, GreenDelta 2015) directly from the US Federal LCA Digital Commons Life Cycle Inventory Unit Process Templates using an OpenLCA plug-in. The OpenLCA model was reviewed to ensure that all inputs and outputs, quantities, units, and metadata were correctly imported. Associated metadata for each unit process was recorded in the unit process templates and imported into OpenLCA along with the model values.

Once all necessary data were imported into the OpenLCA software and reviewed, system models were created for each fuel and country combination. The models were reviewed to ensure that each elementary flow (e.g., environmental emissions, consumption of natural resources, and energy demand) was characterized under each impact category for which a characterization factor was available. The draft final system models were also reviewed prior to calculating results to make certain all connections to upstream processes and weight factors were valid. LCIA results were then calculated by generating a contribution analysis for the selected fuel product system based on the defined functional unit of 1 GJ of delivered heat for cooking.

3. LIFE CYCLE ASSESSMENT RESULTS FOR INDIA

This section presents cookstove fuel LCA results for India first by individual cooking fuel type, followed by fuel mix scenario.

3.1 Results for India by Cooking Fuel Type

The following ten sections provide the results analysis of the LCI and LCIA categories for the individual fuels used within India. Results are provided in graphical format in this section and companion tables for each figure are provided in APPENDIX B: DETAILED LCA RESULTS TABLES. The impact scores depicted here are based on LCI data catalogued in APPENDIX A: DETAILED LCI UNIT PROCESS TABLES.

3.1.1 Global Climate Change Potential

Figure 3-1 displays the GCCP results for India for each cookstove fuel included in this study. Fossil fuel GCCP impacts are dominated by combustion emissions in the cookstove use stage. Coal has the highest impacts, since it is derived from non-renewable carbon and the thermal efficiency of coal stoves (15.5%) is relatively low compared to stoves for the other fossil fuel options (e.g., LPG stove efficiency is 57%). Electricity in India is derived from a mix of coal and petroleum fuels as well as some other sources such as hydropower, which is the primary reason its impacts fall between coal usage and fuels derived from crude oil or natural gas. For consistency with other fuels, fuel combustion emissions associated with electricity generation are shown in the use stage here, although emissions will not occur at the household level. For electric stoves, emissions instead occur at the point of combustion in the power plant. Biogas GCCP impacts are primarily from methane leakage during the production of biogas in an anaerobic digester. Sugarcane ethanol, dung cake (from animals consuming biomass to produce the dung), and unprocessed crop residues are derived from renewable biomass that removed CO_2 from the atmosphere during growth; therefore, the CO_2 emissions released from combustion of these fuels is considered carbon neutral. Methane emissions from the animals producing the dung for the dung cake is also modeled as outside the system boundaries of this work, with these emissions being allocated to the primary animal product (e.g. dairy). Impacts for these renewable fuels during the use phase are driven by nitrous oxide and methane emissions during cookstove use. Impacts associated with fertilizer production and emissions from fertilizer application also play a role in the sugarcane ethanol overall impacts.

Based on the trend in forest area and the annual generation of biomass per hectare, a little less than 60% of the firewood required for cooking can be sustainably sourced; therefore, the combustion emissions for the non-renewable 41% of wood are not considered carbon-neutral. This adjustment is also applied to other wood fuels (wood-derived charcoal and the wood portion of biomass pellets). For charcoal, GCCP impacts for carbonization of the wood in the kiln are comparable in magnitude to the emissions from combustion of the charcoal in a cookstove. Charcoal kiln impacts are largely driven by the methane emissions during the carbonization process.

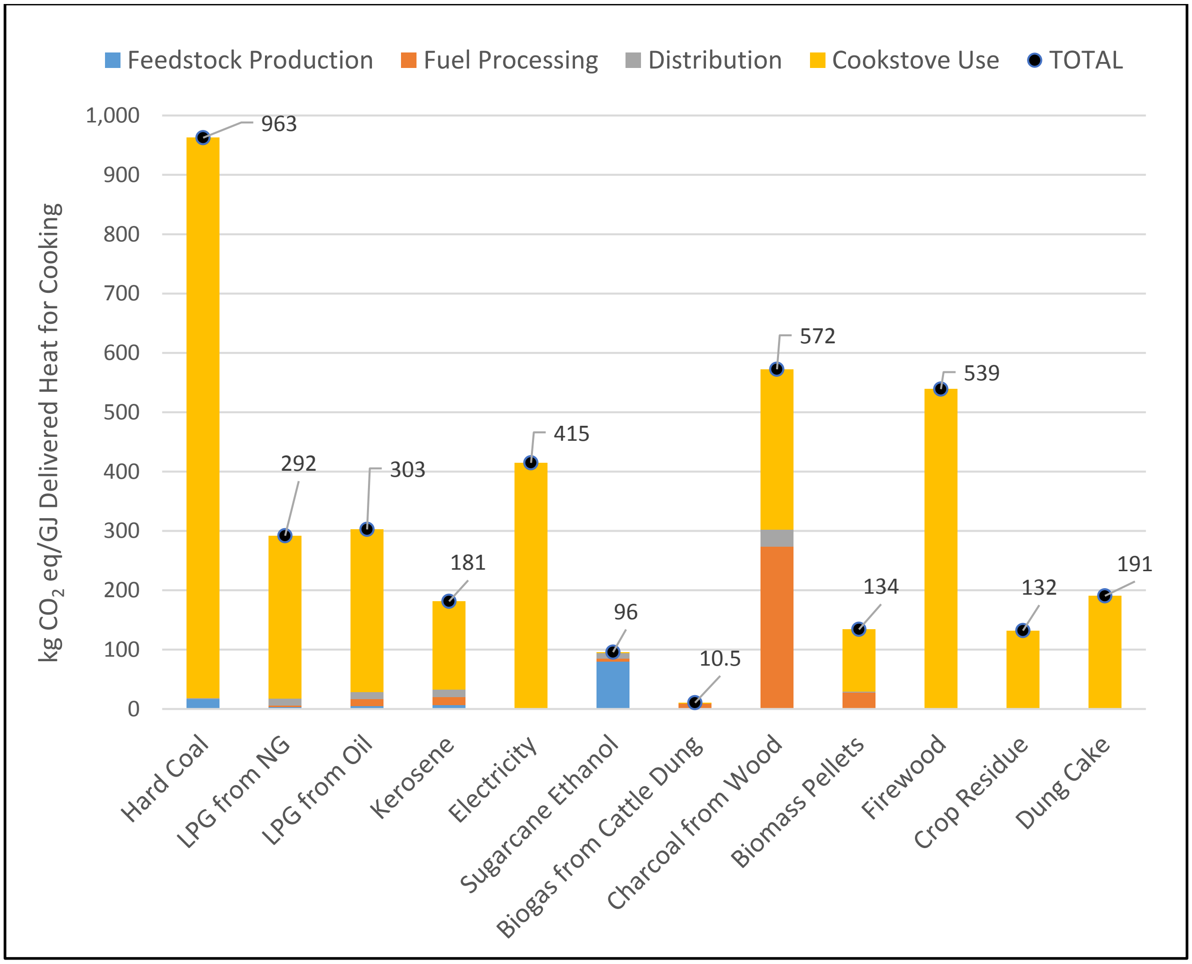


Figure 3-1. Cookstove Fuel Global Climate Change Potential for India

3.1.2 Cumulative Energy Demand

Figure 3-2 displays the CED results for India for each cookstove fuel included in this study. Energy demand results are shown here at the point of use of the relevant energy source.

The results here are largely a function of the fuel heating value and thermal efficiency of the fuel-stove combination. Stoves with higher efficiencies (e.g. LPG, kerosene, biogas, ethanol, and biomass pellets) have a lower CED overall, because more of the heating value of the fuel is converted into useful cooking energy and therefore less fuel must be produced, transported, and burned to deliver the same amount of cooking energy.

A number of observations can be made regarding energy results for the various types of fuels. For sugarcane ethanol, the feedstock energy results include not only the energy value of the sugar that is converted to ethanol but also the energy content of the bagasse, which provides the majority of energy used to process the sugarcane to molasses and then to ethanol. A co-benefit of ethanol production is the generation of electricity, which may be exported. As discussed in the Chapter 2 methodology (Section 2.3), this model employs the cut-off allocation methodology; therefore, a credit is not given here to the sugarcane ethanol for exported electricity, so the energy demand impacts for ethanol should be considered as the upper bounds for this cooking fuel type.

For biomass fuels, the biomass pellets have a lower CED than traditional firewood or unprocessed crop residues. Wood pellets typically have a lower moisture content, greater energy content, and greater surface area than the traditional solid biomass, which allows the fuel to combust more efficiently. It is also more common to see improved cookstoves, which have higher stove thermal efficiencies, used in combination with wood pellets in India. Crop residues have a comparably lower stove efficiency than traditional firewood in India, leading to relatively higher cumulative energy demand impacts for crop residue fuels compared to firewood.

For charcoal briquettes from wood, the energy demand impact is relatively high compared to other fuels due to the lower stove efficiencies for metal charcoal stoves in India and the charcoal kiln energy impacts. That is, additional energy is consumed when burning firewood at the kiln to produce charcoal prior to charcoal utilization in a cookstove.

Overall, liquid and gas fuels, as well as processed solid biomass fuels not requiring additional combustion of solid fuel for processing (e.g., wood pellets), lead to the lowest overall cumulative energy demand impacts. Hard coal results in the highest overall cumulative energy demand due to the low coal stove thermal efficiency and the energy required for coal mining and distribution. Dung cake also has comparably high CED impacts, as it is the fuel type associated with the least efficient cookstove.

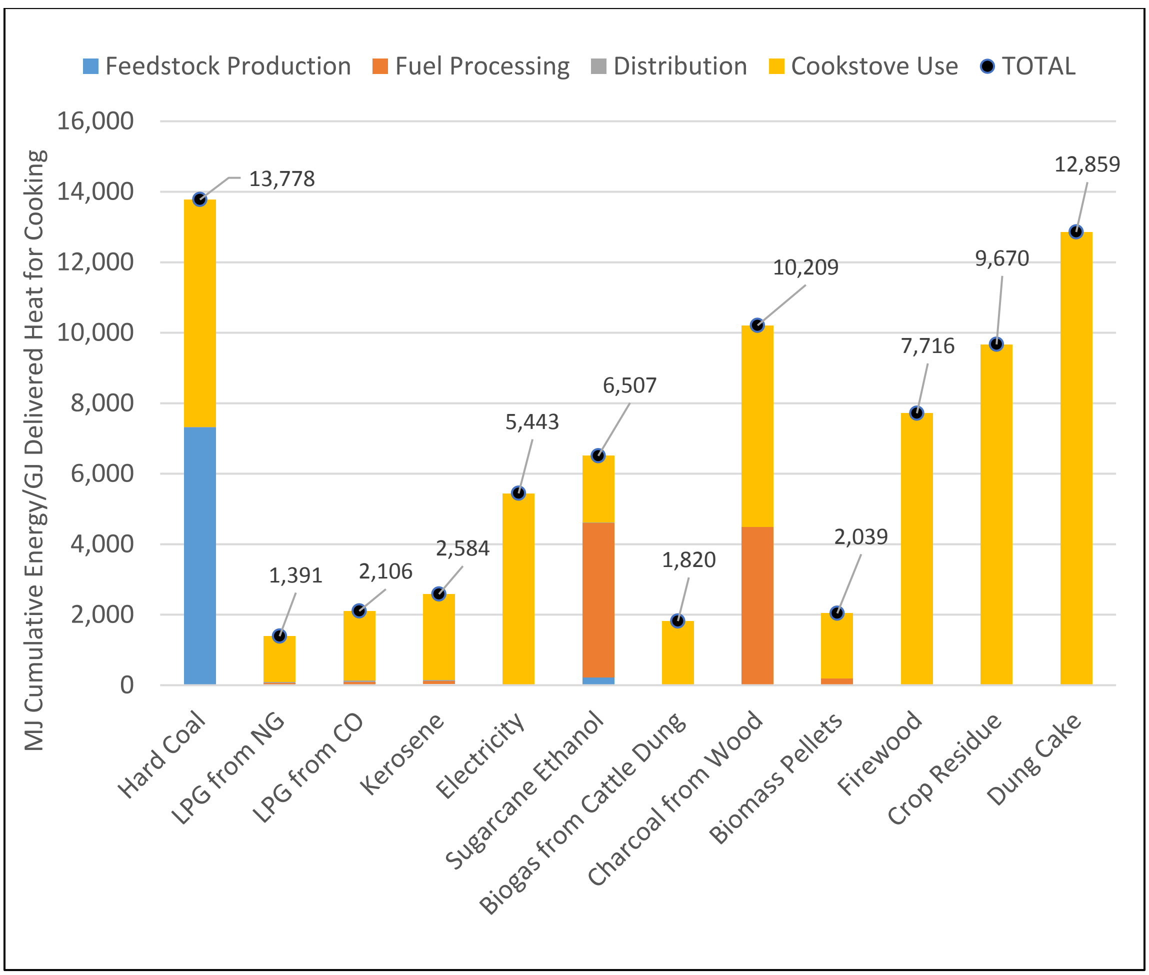


Figure 3-2. Cookstove Fuel Cumulative Energy Demand for India

3.1.3 Fossil Depletion

Figure 3-3 displays the fossil depletion results for India for each cookstove fuel included in this study. All fuels are normalized to kg oil equivalents (eq) based on the heating value of the fossil fuel relative to oil. The fossil depletion associated with traditional biomass fuels and biogas is negligible, as these fuels are not derived from fossil fuel, and collection of these fuels is done manually. While biomass fuels are not derived from fossil fuels, some fossil fuels may be consumed across the life cycle of these fuels for energy inputs to fuel production and processing, distribution, and disposal. Fossil depletion for biomass pellets is associated with electricity usage for pelletization and some transport, while sugarcane ethanol fossil depletion is primarily from fertilizers during cane production, as well as diesel for farm equipment operation and distribution of the feedstock and fuel. Fossil depletion impacts are highest for coal, LPG, kerosene and electricity, as these sources of cooking energy rely on fossil fuels. The greatest impacts are seen for coal. The combination of coal’s lower heating value, measured in MJ/kg, compared to crude oil or natural gas and the lower coal stove thermal efficiency (15.5%) compared to the more efficient LPG stoves (57%) means that more coal than LPG must be burned to get the same amount of cooking energy, leading to the higher fossil depletion for cooking with coal compared to LPG.

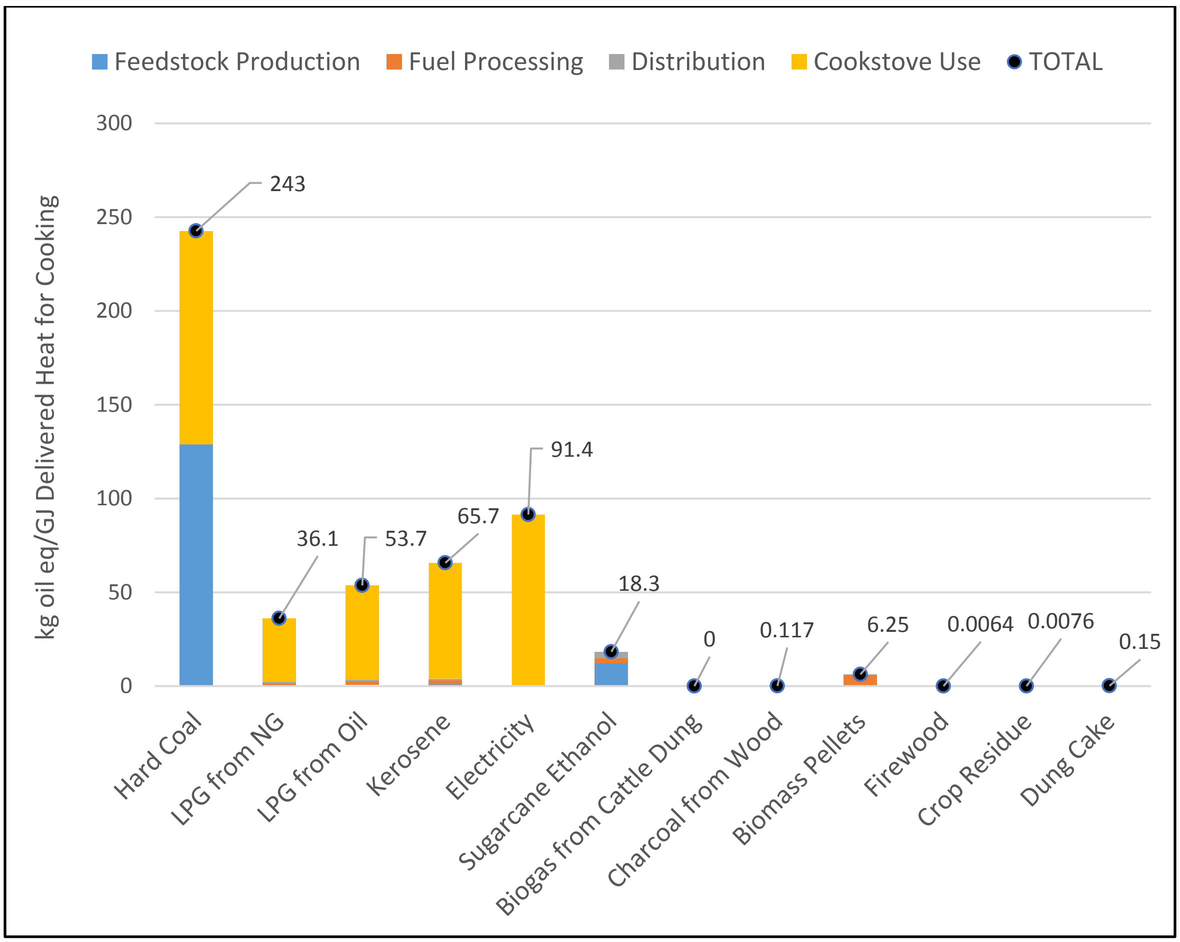


Figure 3-3. Cookstove Fuel Fossil Depletion for India

3.1.4 Water Depletion

Figure 3-4 displays the water depletion results for India for each cookstove fuel included in this study. Water depletion results are based on the volume of fresh water inputs over the life cycle of the assessed fuels. Water may be incorporated in the fuel product, evaporated, or returned to the same or different water body or to land. If the water is returned to the same water body, it is assumed the water is returned at a degraded quality, and therefore is considered consumptive use. Water consumption includes evaporative losses from establishment of hydroelectric dams but does not include the water passing through the turbine, since that water is not removed from its source. The hydropower in the electricity mix drives the overall water depletion impacts. In this case, for simplicity, electricity impacts have been allocated to the use life cycle stage. Water depletion associated with biomass pellets is also due to electricity usage during pelletization. Water depletion impacts are also notable for sugarcane ethanol, as irrigation is required for the cane production. Some water depletion impacts are also seen for the biogas to maintain the digester, but these are negligible when compared to the evaporative losses from hydropower in the electricity grid. Water depletion impacts are negligible for the traditional biomass fuels, which are not irrigated. Because the water content of these fuels comes from the atmosphere as rainfall, the water released back to the atmosphere when the biomass is dried or combusted is not considered consumptive use.

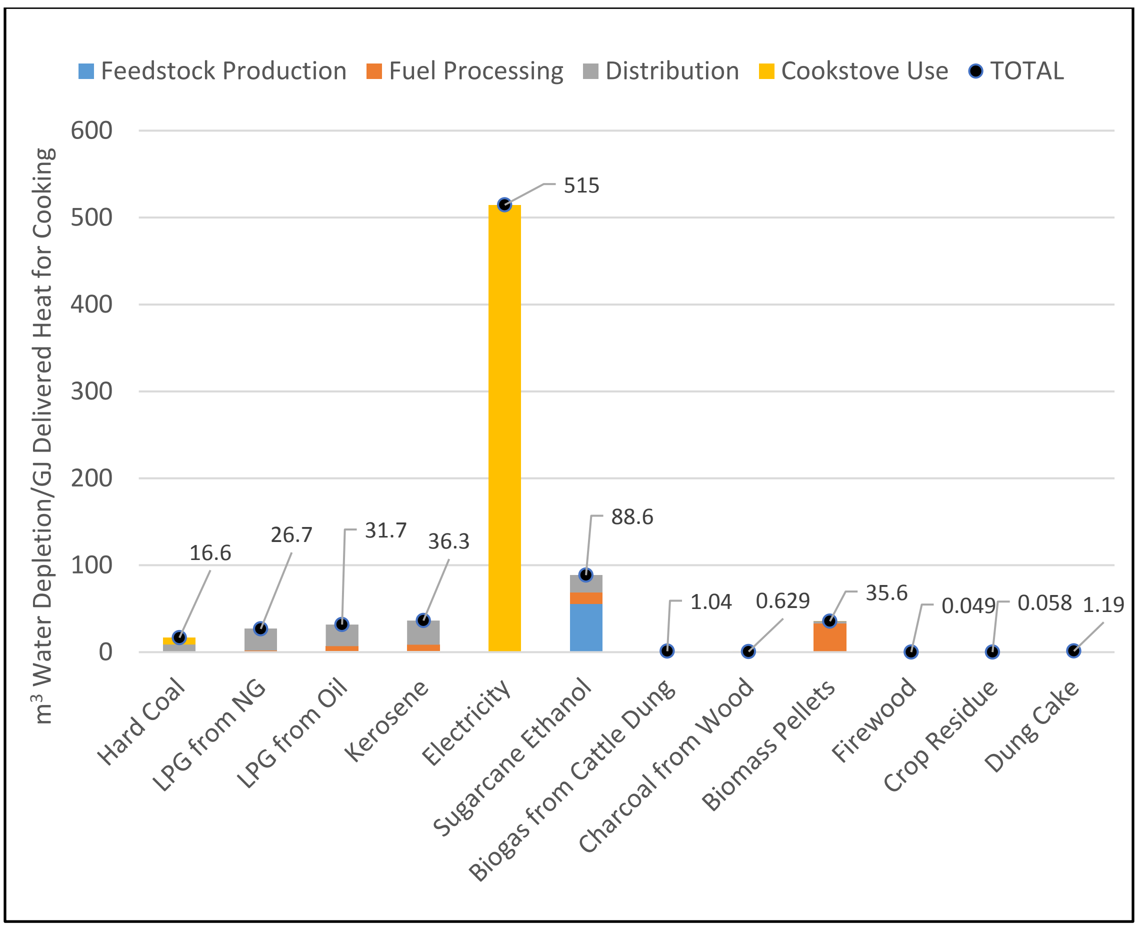


Figure 3-4. Cookstove Fuel Water Depletion for India

3.1.5 Particulate Matter Formation Potential

Figure 3-5 displays the particulate matter formation results for India for each cookstove fuel included in this study. Traditional biomass fuels and hard coal lead to the greatest particulate matter formation impacts, with dung cake having the highest overall impacts. Most particulate matter formation impacts occur during cookstove use at the household with the exception of charcoal, where the carbonization of the wood in the kiln dominates the overall life cycle impacts. Advanced liquid fuels as well as biogas and wood pellets have comparably small particulate matter impacts. Most of the particulate matter impacts for electricity are derived from the coal mix in the average Indian electrical grid. The particulate matter impacts from fuel combustion for electricity generation have been allocated to the use phase because even though they do not occur within a household, they are emitted at the point of combustion in the power generating facility.

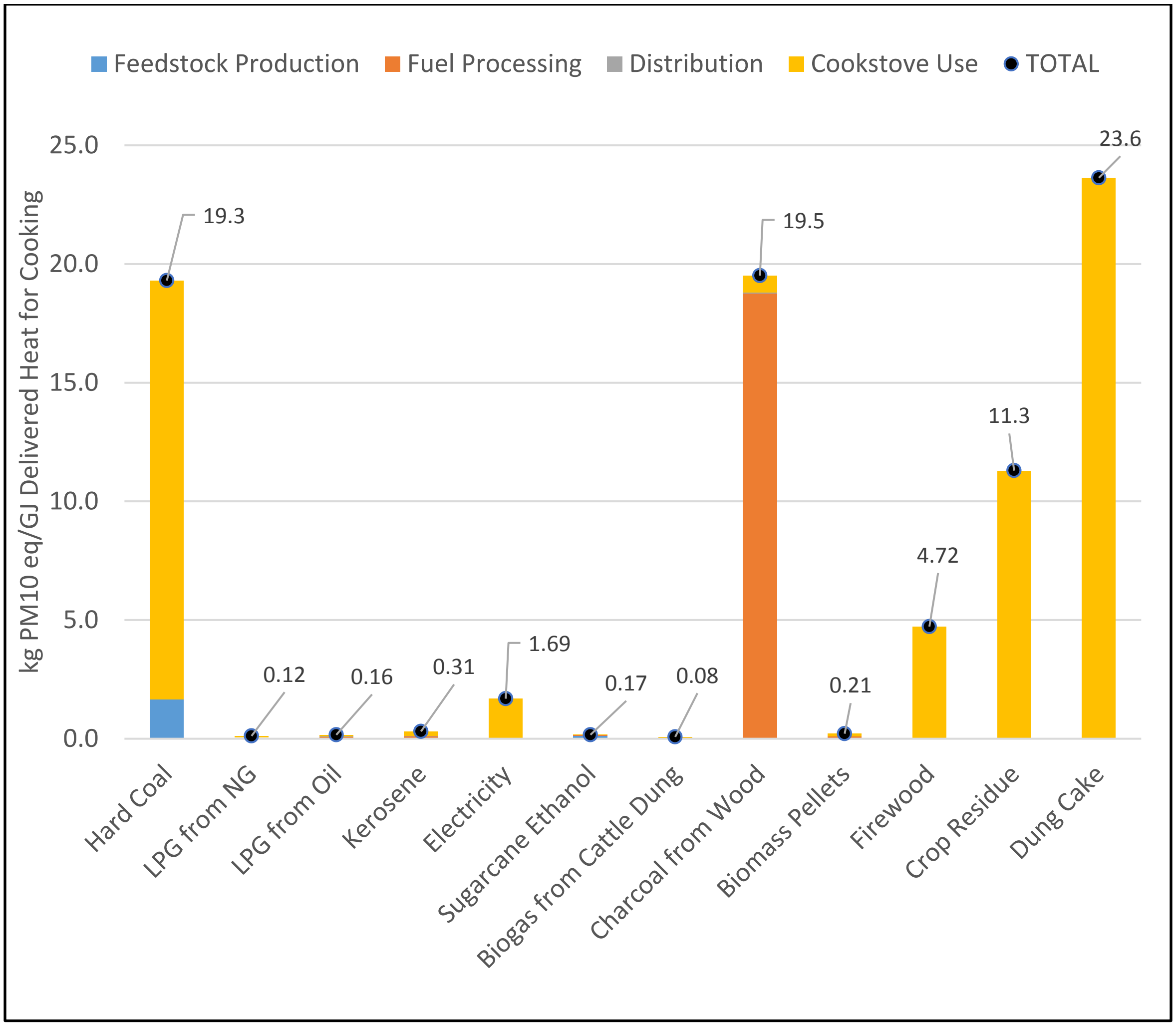


Figure 3-5. Cookstove Fuel Particulate Matter Formation Potential for India

3.1.6 Photochemical Oxidant Formation Potential

Figure 3-6 displays the photochemical oxidant formation results for India for each cookstove fuel included in this study. Traditional biomass fuels and hard coal lead to the greatest photochemical formation impacts, with dung cake having the highest overall impacts. For charcoal, impacts are split between the fuel processing stage (carbonization in a kiln) and the use stage. Photochemical oxidant impacts for electricity are primarily associated with utilization of hard coal in the grid mix. Impacts from fuel combustion emissions for electricity generation are shown in the use stage here for simplicity, although the contributing emissions are not released at the household level. Photochemical oxidant formation impacts are relatively small for the liquid fuels, biomass pellets and biogas.

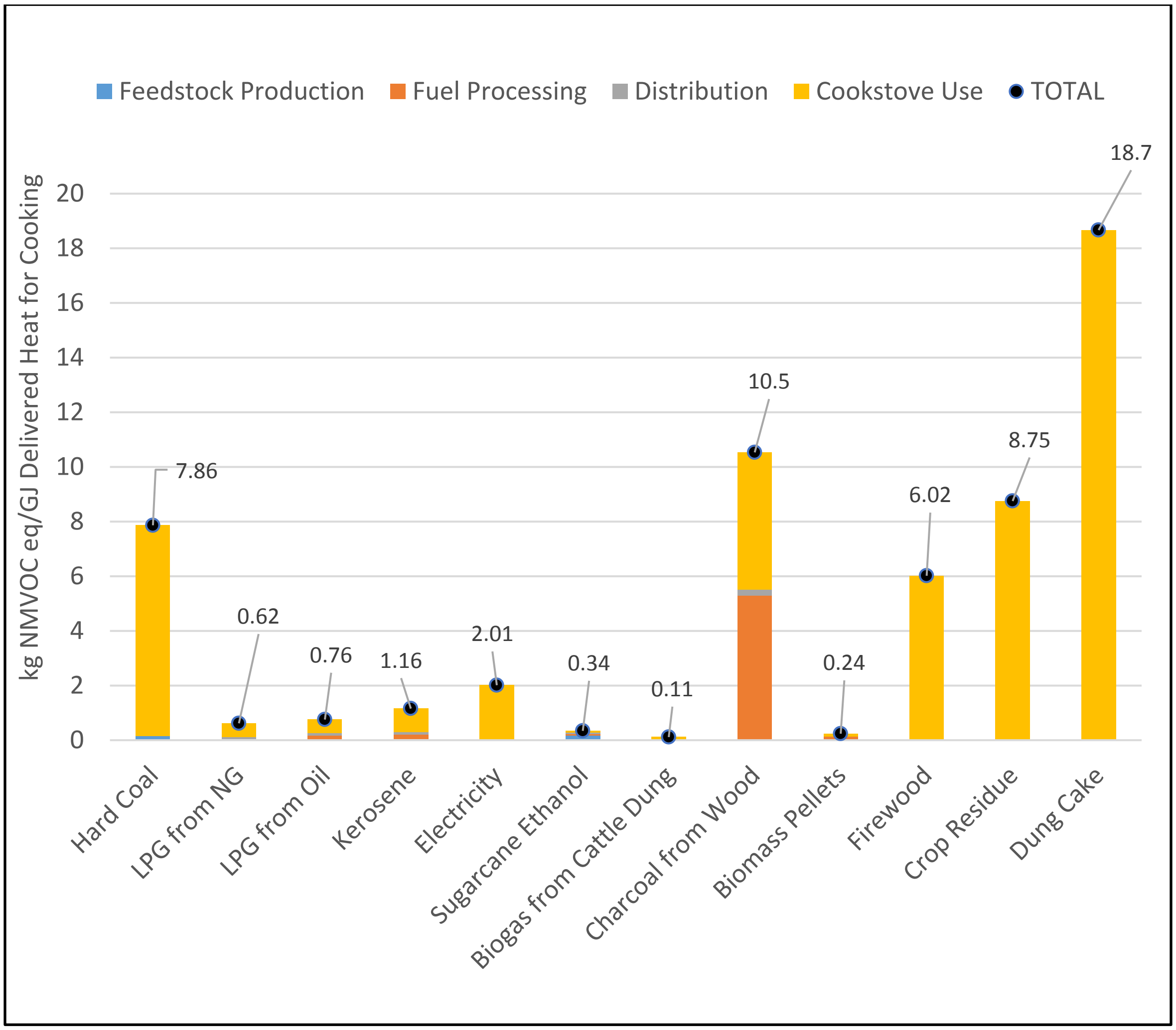


Figure 3-6. Cookstove Fuel Photochemical Oxidant Formation Potential for India

3.1.7 Freshwater Eutrophication Potential

Figure 3-7 displays the freshwater eutrophication results for India for each cookstove fuel included in this study. Dung cake results in the highest eutrophication potential impacts because of the much larger ash quantity produced from dung cake compared to all other fuels. The ash from the traditional fuels is assumed to be land applied, which leads to relatively high eutrophication impacts, assuming runoff into water bodies, for most traditional fuels. While impacts are comparably smaller for ethanol, some eutrophication impacts occur from use of phosphorus based fertilizer in sugarcane production. There are no eutrophication impacts associated with biogas. Application of the digested sludge from the biogas system would lead to some eutrophication impacts, but utilization of this co-product is outside the system boundaries of this study. The digested sludge impacts are allocated to the product system it serves (e.g. nutrients for crop production). Impacts from fossil based fuels and biomass pellets are minimal compared to the traditional fuels.

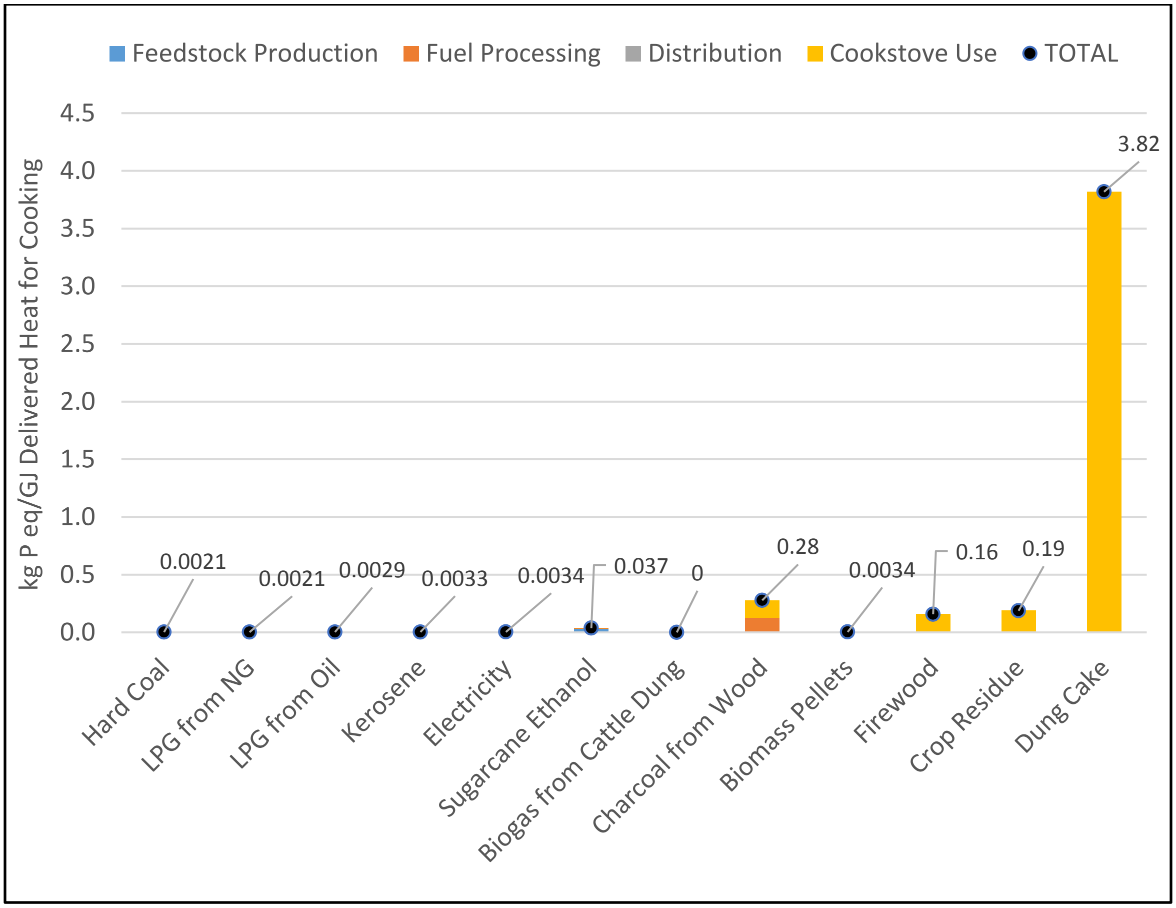


Figure 3-7. Cookstove Fuel Freshwater Eutrophication for India

3.1.8 Terrestrial Acidification Potential

Figure 3-8 displays the terrestrial acidification results for India for each cookstove fuel included in this study. Acidification impacts are dominated by coal usage, either as a direct fuel or as an input to electricity generation. Electricity usage for pelletization is the main source of biomass pellet acidification impacts. Sulfur dioxide emissions from coal are notably higher than sulfur dioxide emissions from combustion of other fuels. Ethanol contains no sulfur, so there are no sulfur dioxide emissions for the ethanol cookstove use stage. No NOx emissions data for ethanol combustion in a cookstove were available, although ethanol combustion typically leads to minimal nitrogen oxide emissions. Traditional fuels, specifically crop residues and dung cake, have slightly higher acidification impacts than the liquid fuels. The lowest overall acidification impacts are seen for biogas. Again, the land applied digested sludge from biogas production is considered outside the system boundaries. It is possible this land applied digested sludge would lead to emissions of ammonia, an acidifying substance.

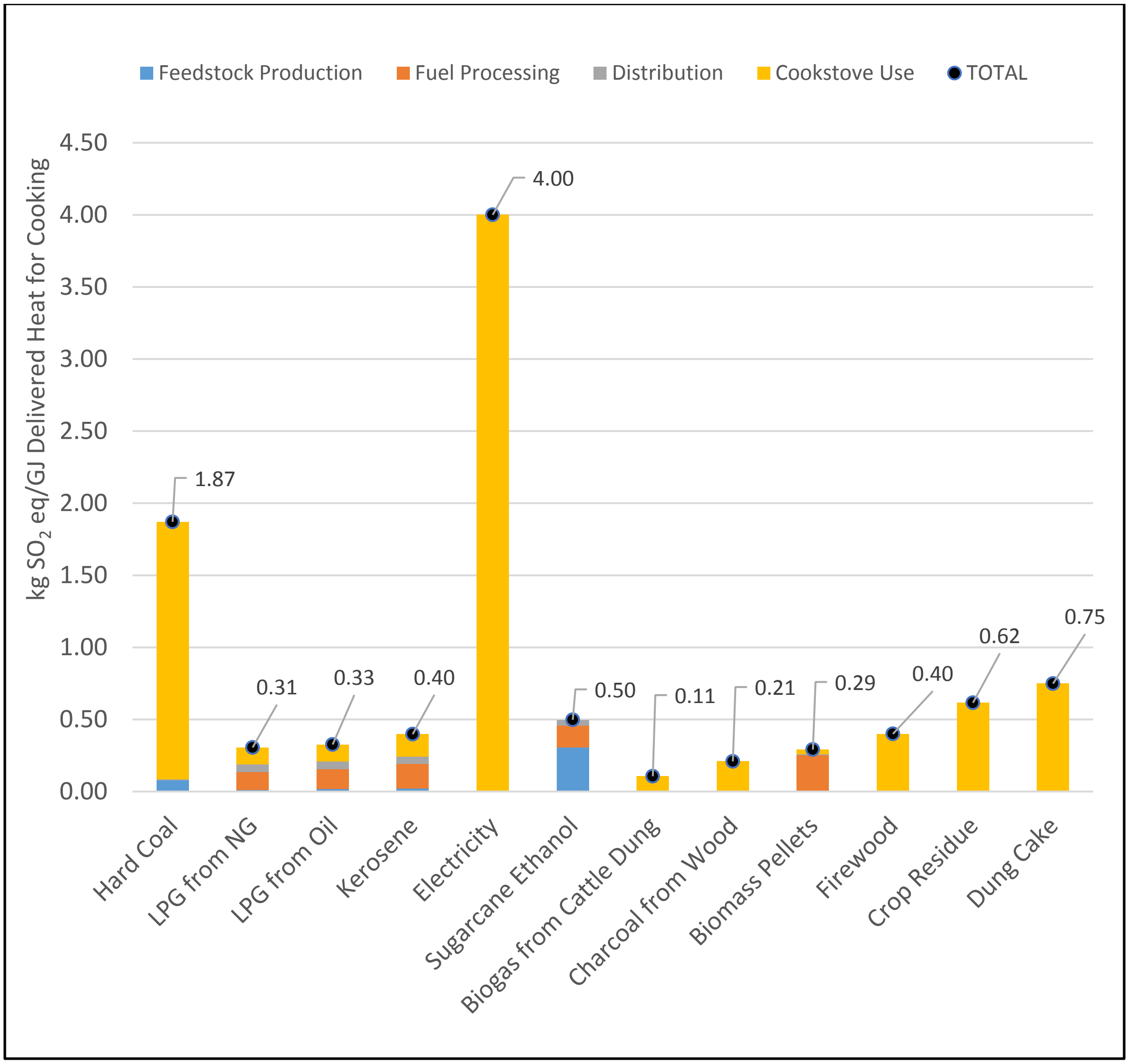


Figure 3-8. Cookstove Fuel Terrestrial Acidification for India

3.1.9 Ozone Depletion Potential

Figure 3-9 displays the ozone depletion results for India for each cookstove fuel included in this study. Ozone depletion impacts are greatest for the fossil fuels, as well as sugarcane ethanol. For petroleum products, impacts are split between the fuel processing and distribution stage. This ozone depletion generally comes from halon 1301 emissions in crude oil production. For sugarcane ethanol, herbicide production and other fertilizer production drives the ozone depletion impacts. Ozone depletion impacts are negligible for traditional fuels as well as biogas. Overall, normalized ozone depletion impacts are on a much smaller magnitude than other indicators covered, suggesting that less importance should be placed on this indicator when assessing fuel options.

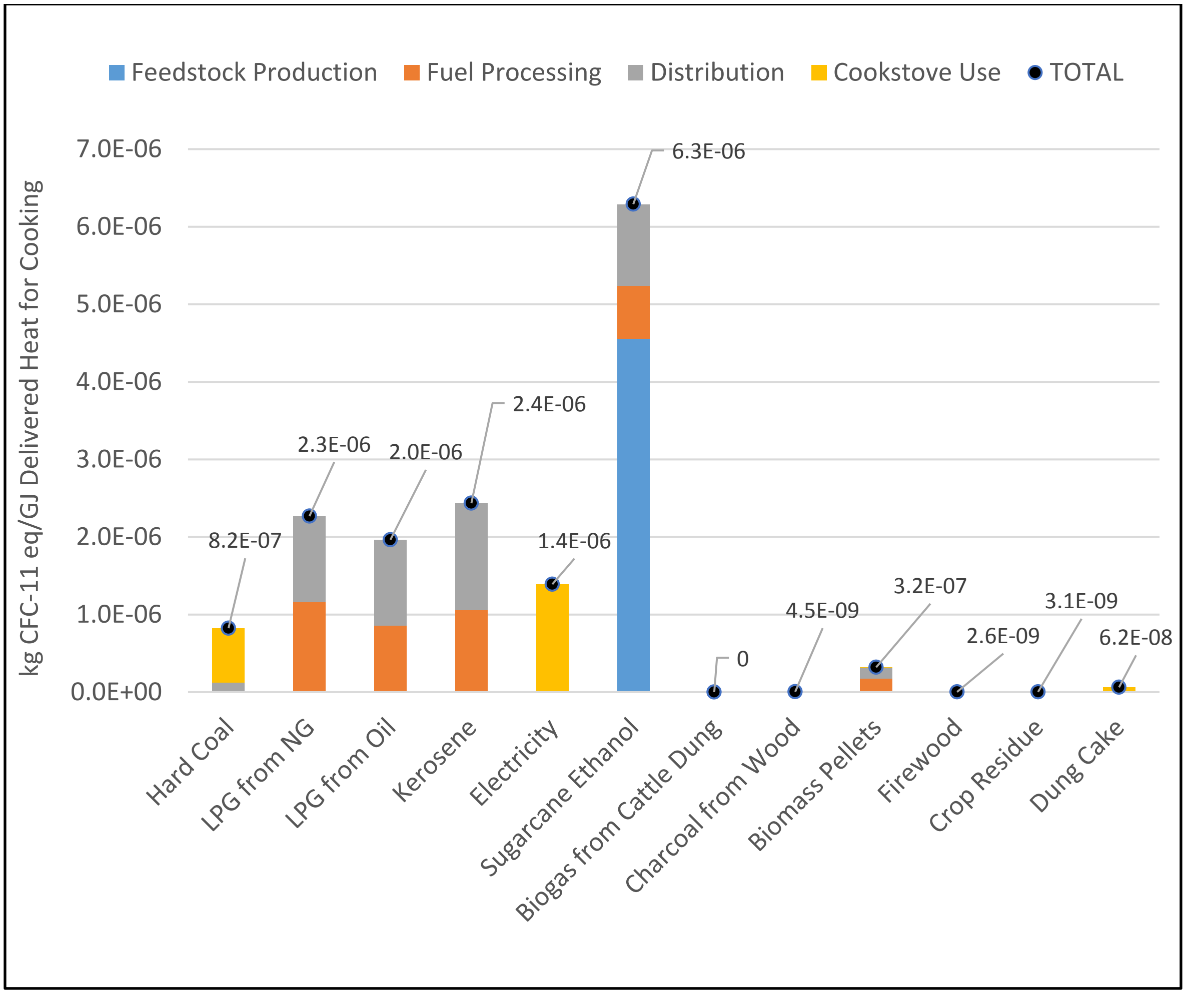


Figure 3-9. Cookstove Fuel Ozone Depletion Potential Impacts for India

3.1.10 Black Carbon and Short-Lived Climate Pollutants

Figure 3-10 displays the black carbon results for India for each cookstove fuel included in this study. The highest BC impacts are seen for traditional unprocessed biomass fuels as hard coal, which tends to have high particulate matter emissions when combusted, and charcoal. For charcoal, the largest share of particulate matter is seen for fuel processing in the charcoal kiln, which combusts wood to carbonize the fuel. Utilization of the liquid and gas fuels result in the lowest overall BC impacts. Some life cycle stages have negative BC equivalent impacts, which is the case when emissions of SOx and organic carbon, pollutants with net cooling effects on the climate, are greater than the emissions of BC and other co-emitted pollutants that lead to short term warming impacts.

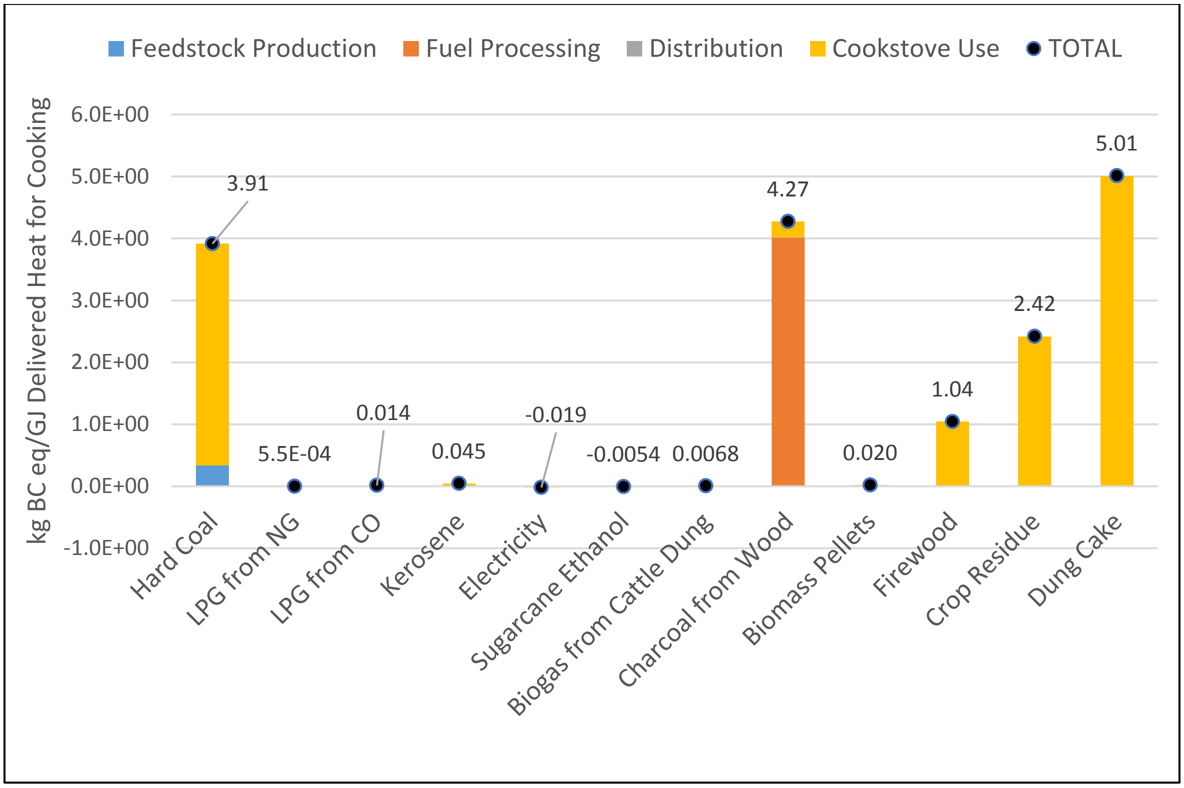


Figure 3-10. Cookstove Fuel Black Carbon and Short-Lived Climate Pollutant Impacts for India

3.2 <u>Results for India by Baseline and Potential Scenarios</u>

Given the magnitude of impacts resulting from the use of cookstoves on both the environment and human health it is important to consider how future changes in cookstove fuel mix might affect these impacts. Eight potential fuel use scenarios were developed in order to explore how impacts in each of the ten studied environmental impact categories may change in the future. Table 1-4 lists the current and eight potential future fuel use scenarios in India along with the abbreviated scenario names that are used to refer to each scenario in figures and text in the following sections.

3.2.1 Global Climate Change Potential

Figure 3-11 presents the GCCP results for the current and potential future cookstove fuel mix scenarios. All of the potential future fuel mix scenarios result in less GCCP, with the 'LPG Replaces Biomass' and 'Biogas Replaces Biomass' scenarios having the lowest impacts. However, the difference in climate change potential between the current scenario and the future scenarios is not large. Firewood contributes the most to global climate change across all scenarios, followed by LPG from crude oil. Although wood is generally considered a renewable resource, the portion of greenhouse gas emissions from combustion of the non-renewable portion of wood fuel are not considered carbon neutral and are therefore counted towards the GCCP. Another fraction of the GCCP from firewood, as well as from other traditional biomass fuels, is due to formation of methane and nitrous oxide emissions during fuel combustion in the cookstove.

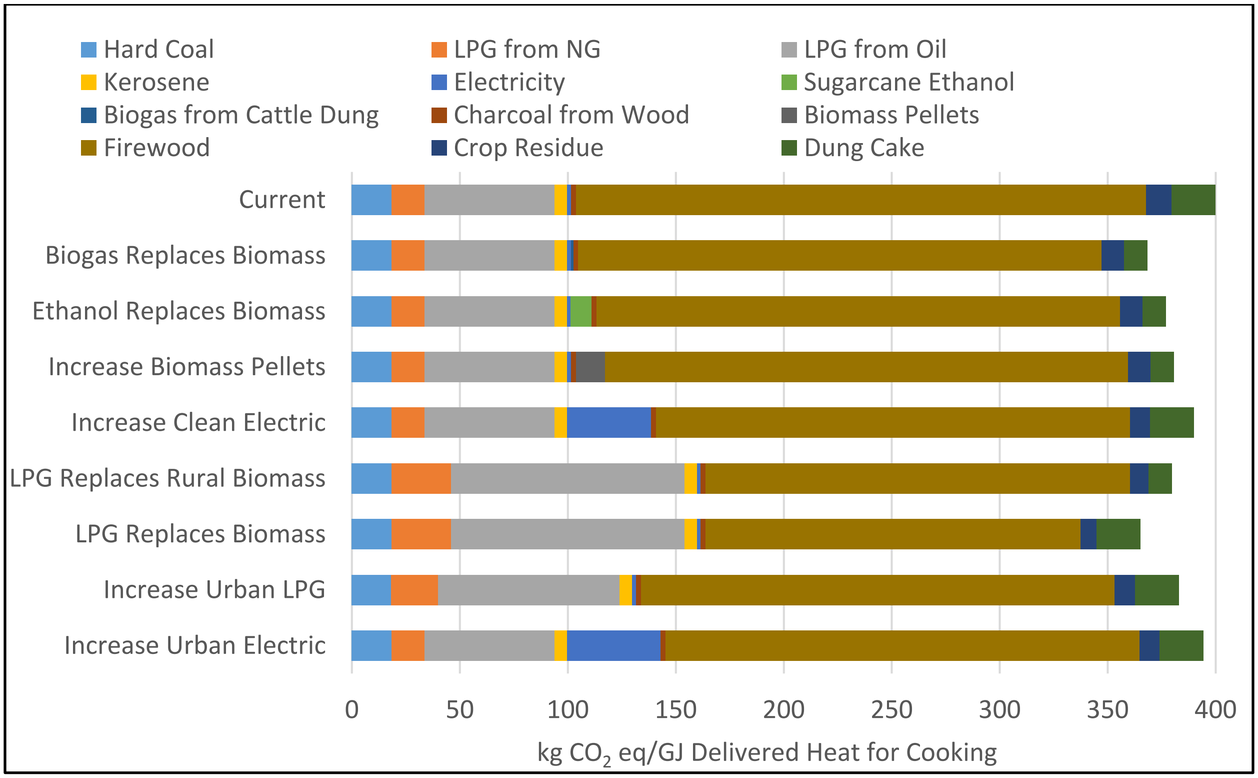


Figure 3-11. Global Climate Change Potential Impacts for Current and Future Fuel Mix Scenarios in India

3.2.2 Cumulative Energy Demand

Figure 3-12 displays the CED results for each scenario in India. Currently, firewood contributes more than half of total CED while the next largest contributor, dung cake makes up less than a quarter of total CED. All of the future fuel mix scenarios lead to a decrease in CED, but the reductions due to the 'Increase Clean Electric' and 'Increase Urban Electric' scenarios are minimal. The scenarios that are most effective in lowering CED are those that involve replacing a portion of firewood, crop residue, and dung use with another fuel. Replacement of biomass and dung with LPG in particular results in considerably less CED than the current cookstove fuel mix in India. However, even in the scenarios that involve reductions in firewood use, firewood remains the dominant source of CED.

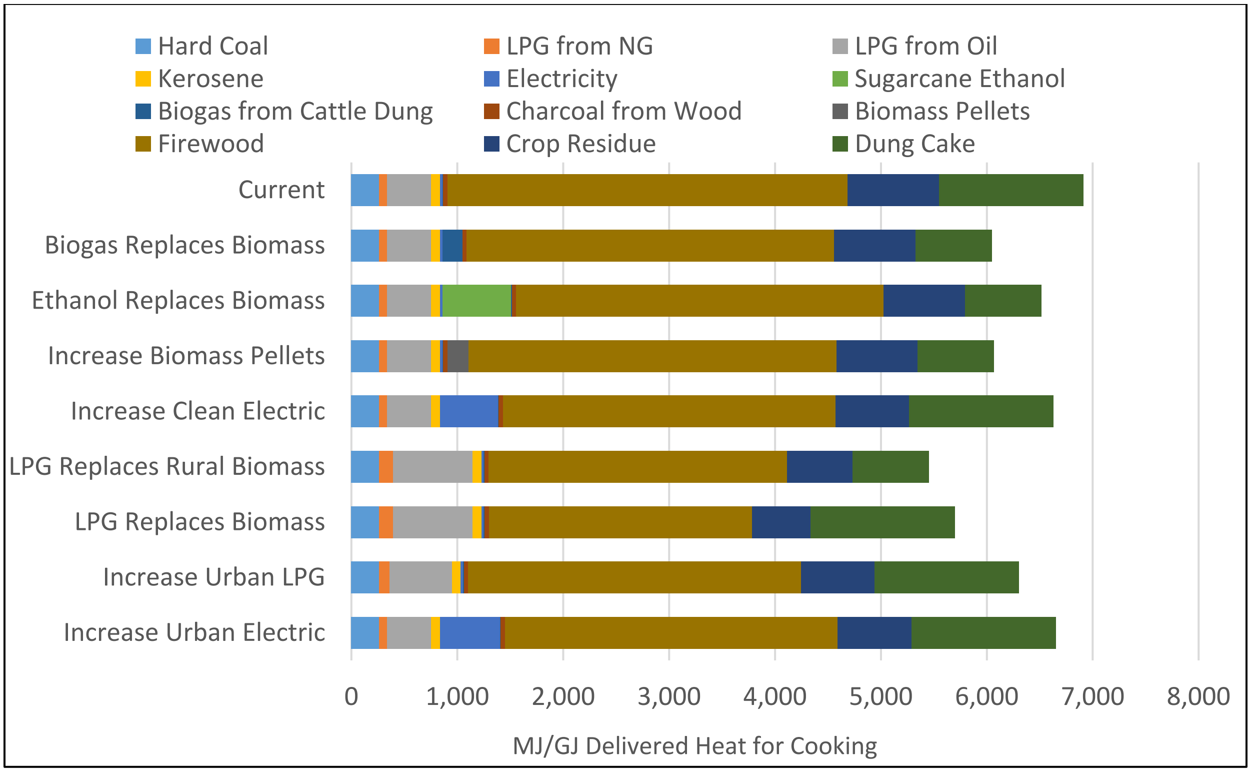


Figure 3-12. Cumulative Energy Demand for Current and Future Fuel Mix Scenarios in India

3.2.3 Fossil Depletion

Figure 3-13 depicts the depletion of fossil fuels as a result of the current and future cookstove fuel mix scenarios. Currently in India, the greatest source of fossil depletion in the cooking fuel mix is LPG from crude oil, followed by hard coal. Kerosene, LPG from natural gas, and electricity are other lesser contributors. Use of biomass fuels results in zero or negligible fossil depletion impacts. While substituting biogas use in cookstoves for a portion of the traditional biomass used in India today would result in no change in overall fossil depletion, the remaining potential future scenarios would all result in higher fossil depletion. The highest impacts are seen for the scenarios where LPG replaces some of the current biomass usage or when use of current grid mix electricity for cookstoves is increased, since much of electricity in India is generated from coal combustion. The 'Ethanol Replaces Biomass' scenario also results in slightly higher fossil depletion since sugarcane farming uses more fossil fuel inputs than gathering and processing traditional biomass fuels.

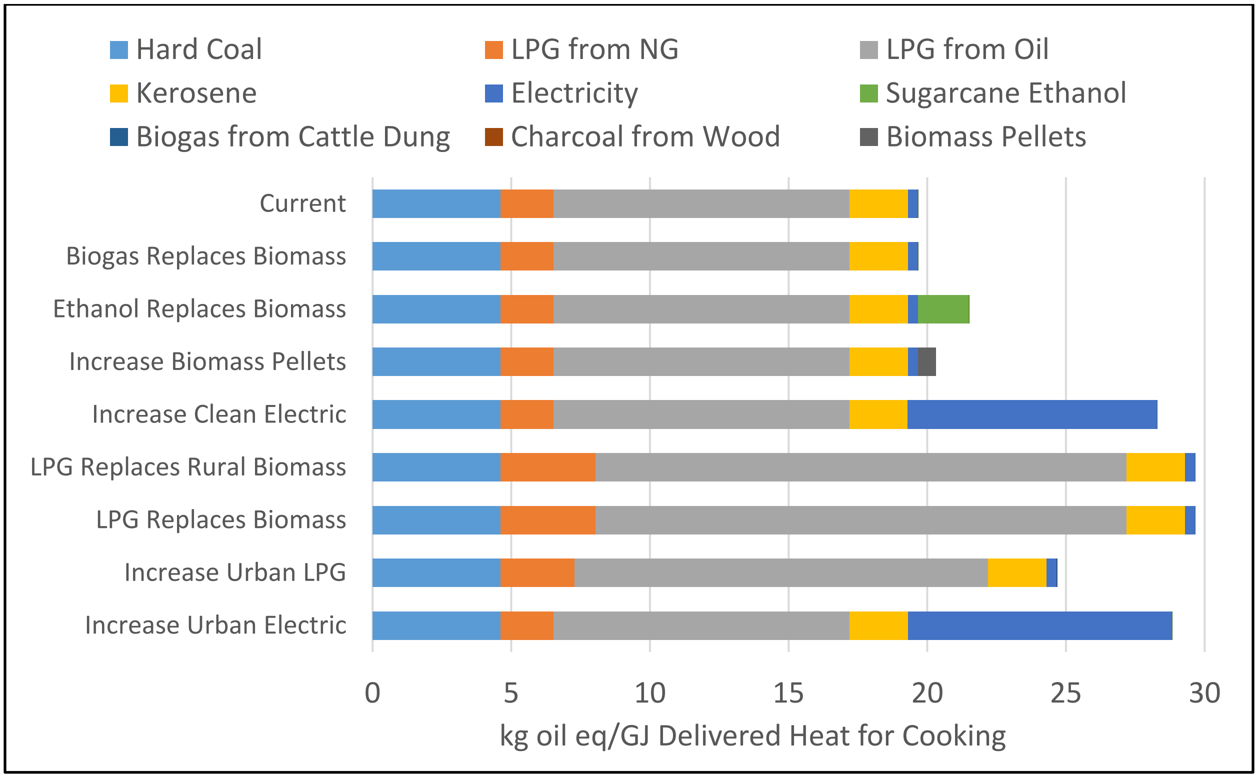


Figure 3-13. Fossil Depletion for Current and Future Fuel Mix Scenarios in India

3.2.4 Water Depletion

Figure 3-14 shows that the current mix of cookstove fuels in India has lower water depletion results compared to the future scenarios investigated in this study. 'Increase Clean Electric' and 'Increase Urban Electric' scenarios would cause 6.6 and 5.5 times the amount of water depletion resulting from the current scenario, respectively. Evaporative water loss related to hydroelectric dams drives the high water depletion impacts associated with increased electricity usage. The 'Increase Clean Electric' scenario includes a greater percentage of hydroelectric power, which results in even greater water depletion than the 'Increase Urban Electric' scenario. Water depletion associated with biomass pellets is also due to electricity usage during pelletization. Introducing sugarcane ethanol into the fuel mix would also increase water depletion, since irrigation is required for sugarcane production. In general, replacing traditional biomass fuels that require little water over their life cycle will cause an increase in water depletion.

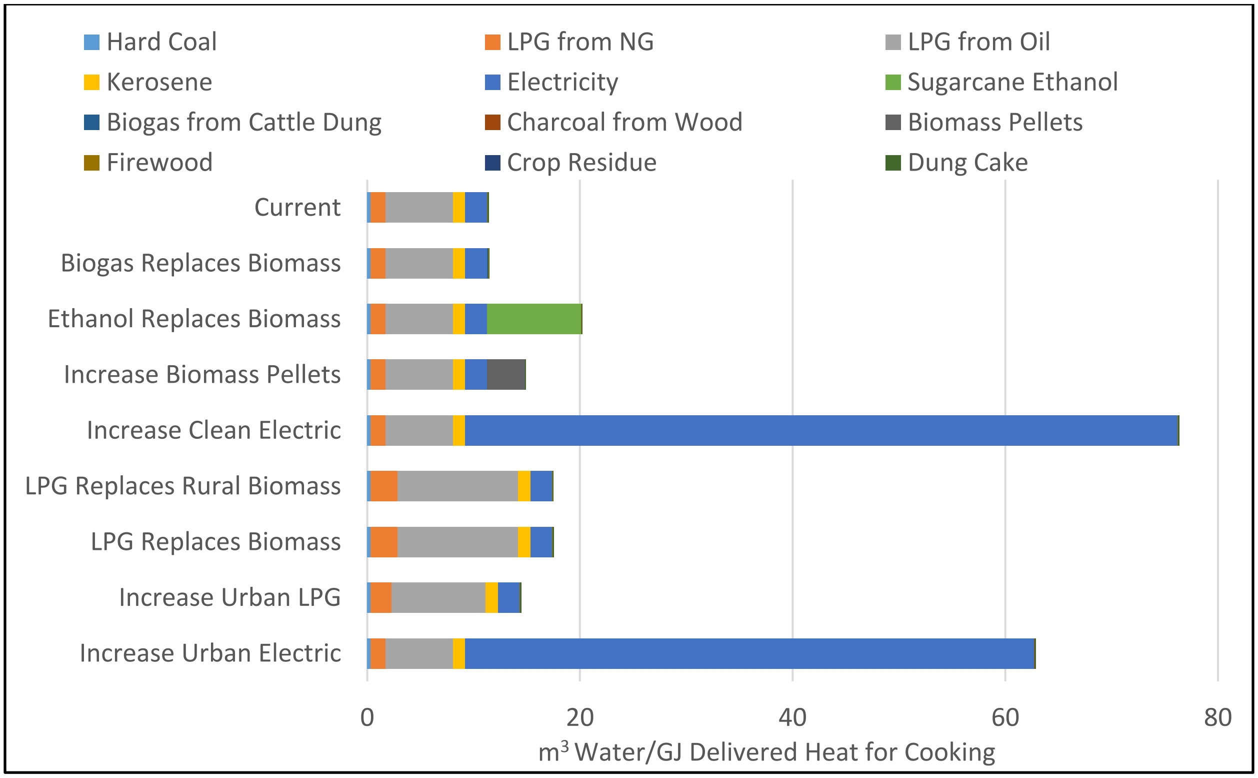


Figure 3-14. Water Depletion for Current and Future Fuel Mix Scenarios in India

3.2.5 Particulate Matter Formation

As seen in Figure 3-15, current particulate matter formation potential could be reduced if any of the potential future cookstove fuel mix scenarios were achieved. Even though an increase in electricity used for cookstoves as modeled in the 'Increase Clean Electric' and 'Increase Urban Electric' scenarios would reduce particulate matter impacts in homes, the particulate matter formation associated with electricity generation from coal means that these scenarios would not greatly reduce life cycle particulate matter impacts. LPG, biogas, biomass pellets, and sugarcane ethanol produce significantly less particulate matter during combustion than traditional biomass fuels, especially dung cake, so particulate matter impacts are reduced the most in the scenarios where these fuels replace a portion of the traditional biomass used currently.

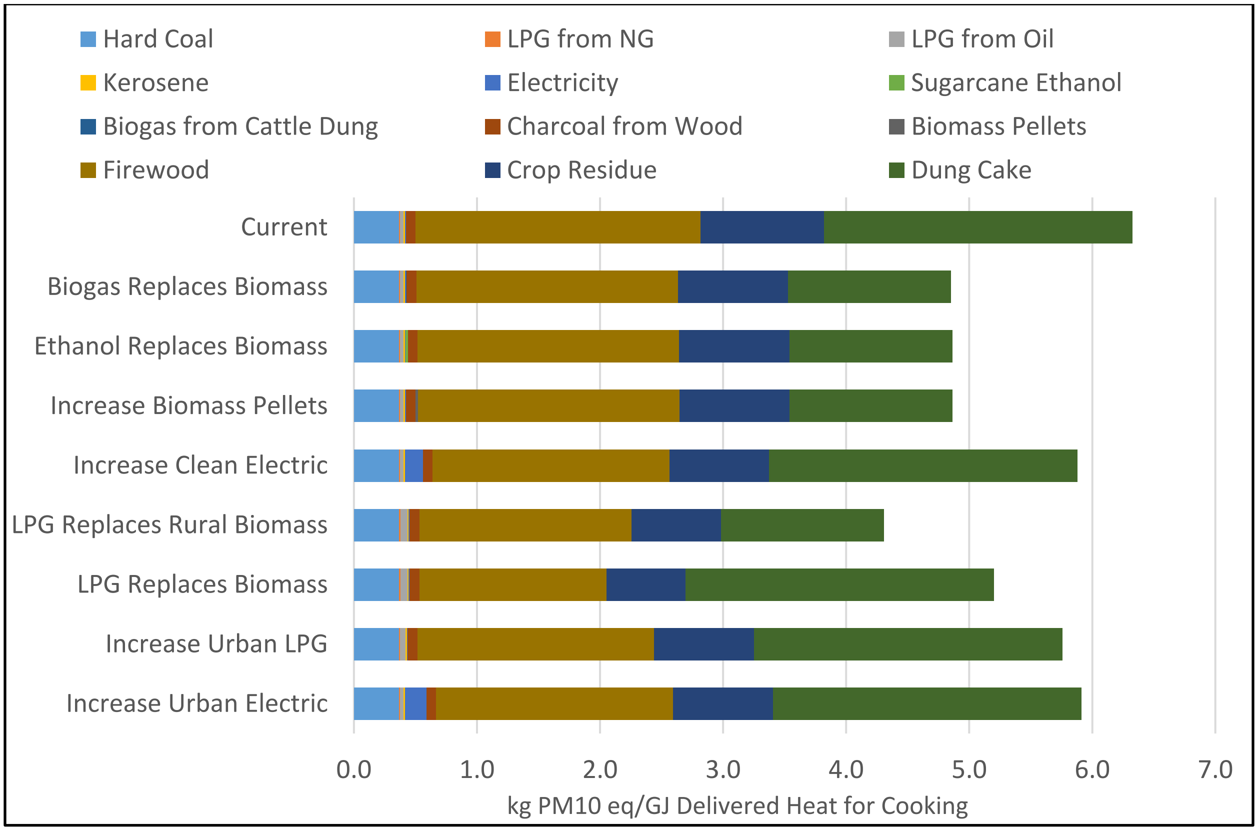


Figure 3-15. Particulate Matter Formation Potential for Current and Future Fuel Mix Scenarios in India

3.2.6 Photochemical Oxidant Formation Potential

Figure 3-16 displays the effect of various fuel use scenarios on photochemical oxidant formation potential impacts. All of the study scenarios lead to improved environmental performance within this impact category when compared to the current scenario. The replacement of biomass fuel with LPG is the scenario that leads to the greatest reduction in photochemical oxidant formation. Both scenarios with increased use of electricity as a cooking fuel lead to only marginal improvements over the current Indian fuel mix scenario. Firewood, crop residues, and dung cake are the dominant fuels contributing to impacts within this category across all of the study scenarios.

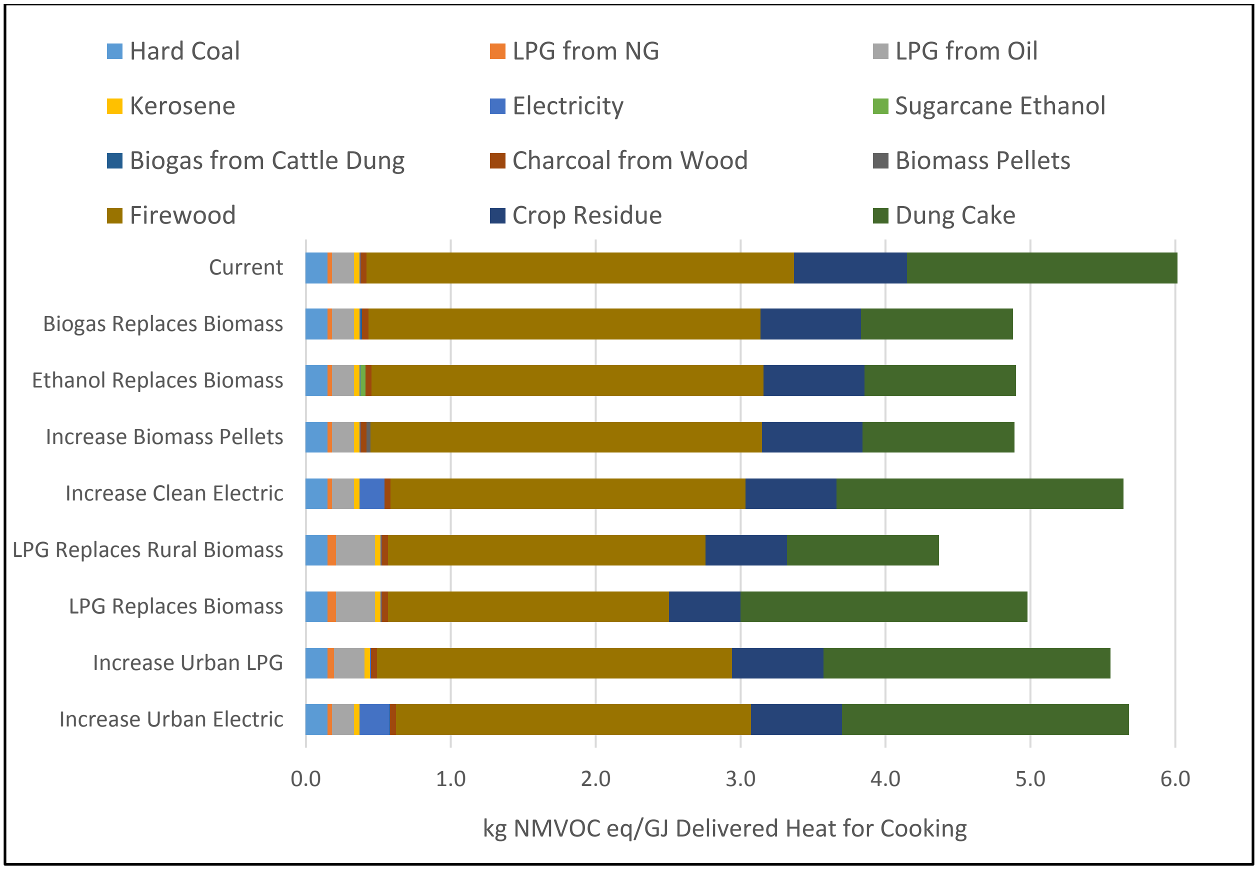


Figure 3-16. Photochemical Oxidant Formation Potential for Current and Future Fuel Mix Scenarios in India

3.2.7 Freshwater Eutrophication Potential

Figure 3-17 depicts the influence of fuel use scenarios on freshwater eutrophication potential impacts. Dung is the predominant fuel contributing to freshwater eutrophication. This is true despite the relatively small contribution of dung cake to the Indian fuel mix, with none of the scenarios utilizing more than 10.6% dung per GJ of delivered cooking heat (Table 1-5). Alternatively, firewood has a relatively modest impact compared to dung per GJ of delivered heat, however it comprises a much more substantial portion of the fuel mix within each scenario, varying between 32 and 49%.

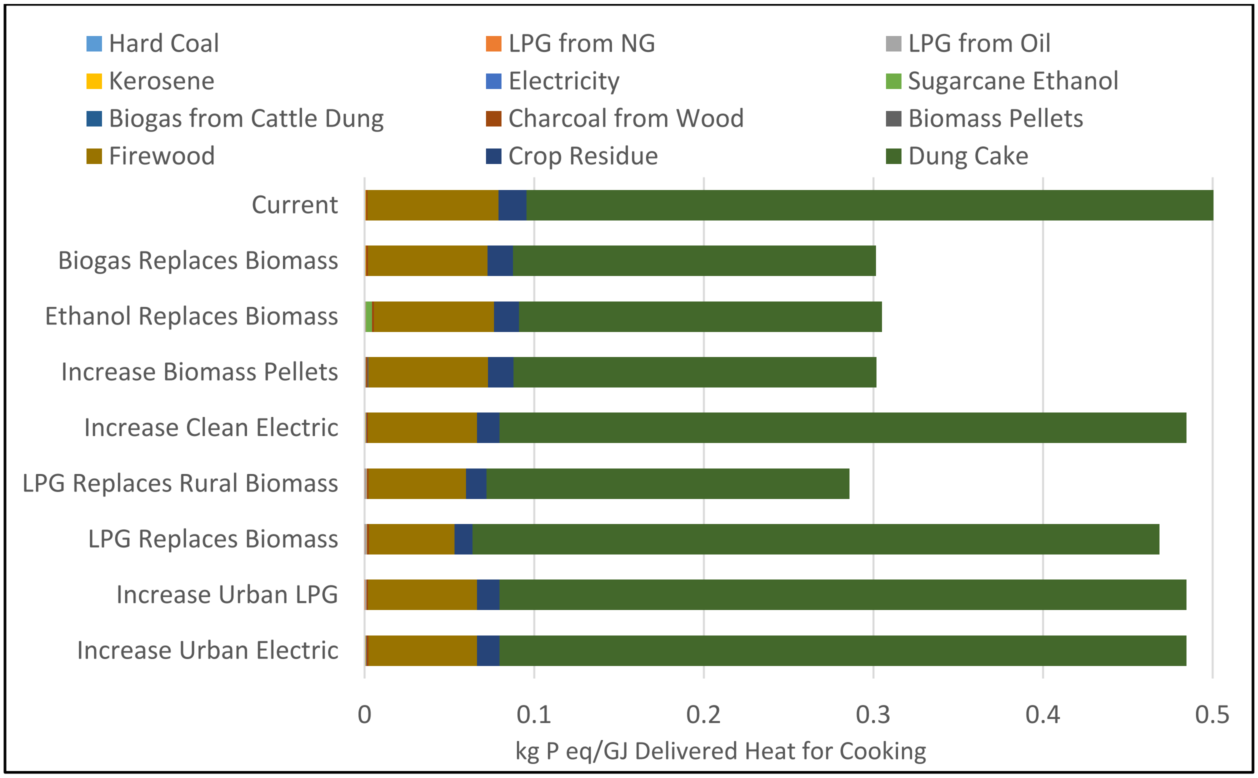


Figure 3-17. Freshwater Eutrophication Potential for Current and Future Fuel Mix Scenarios in India

3.2.8 Terrestrial Acidification Potential

The influence of studied fuel use scenarios on terrestrial acidification potential is displayed in Figure 3-18. Both scenarios in which electricity is increased as a cooking fuel lead to significantly higher acidification impacts than the current scenario. All other scenarios lead to minor improvements when compared against the current scenario. In general, the results in this impact category are driven by coal use, either directly as a cooking fuel or indirectly in the production of electricity.

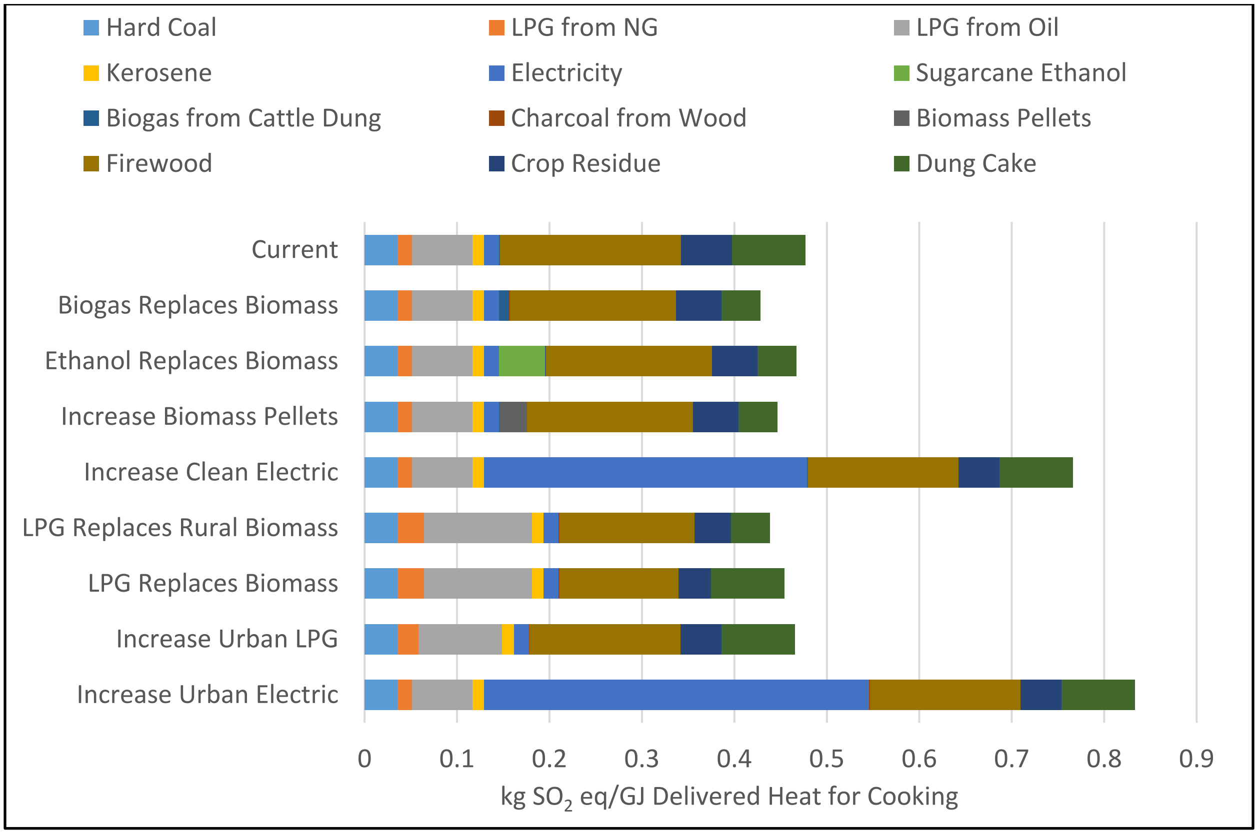


Figure 3-18. Terrestrial Acidification Potential for Current and Future Fuel Mix Scenarios in India

3.2.9 Ozone Depletion Potential

The influence of fuel scenarios on ozone depletion potential impact scores is presented below in Figure 3-19. Unlike many of the other impact categories, the majority of studied scenarios lead to an increase in ozone depletion potential beyond that estimated for the current scenario. The use of LPG, particularly LPG produced from crude oil feedstock, dominates contributions to the studied scenarios in this impact category. Consequently, the scenarios in which LPG is used to replace biomass are two of the three worst performers. Ethanol production has an even more pronounced impact on the scenario in which it is assumed to replace traditional biomass and dung. Ethanol alone contributes approximately half of the ozone depletion impacts while comprising only 10% of the scenarios fuel mix. Ethanol ozone depletion impacts are driven by emissions from application of herbicides during cane production. Electricity use also contributes to impact results in the scenarios in which its use is scaled up.

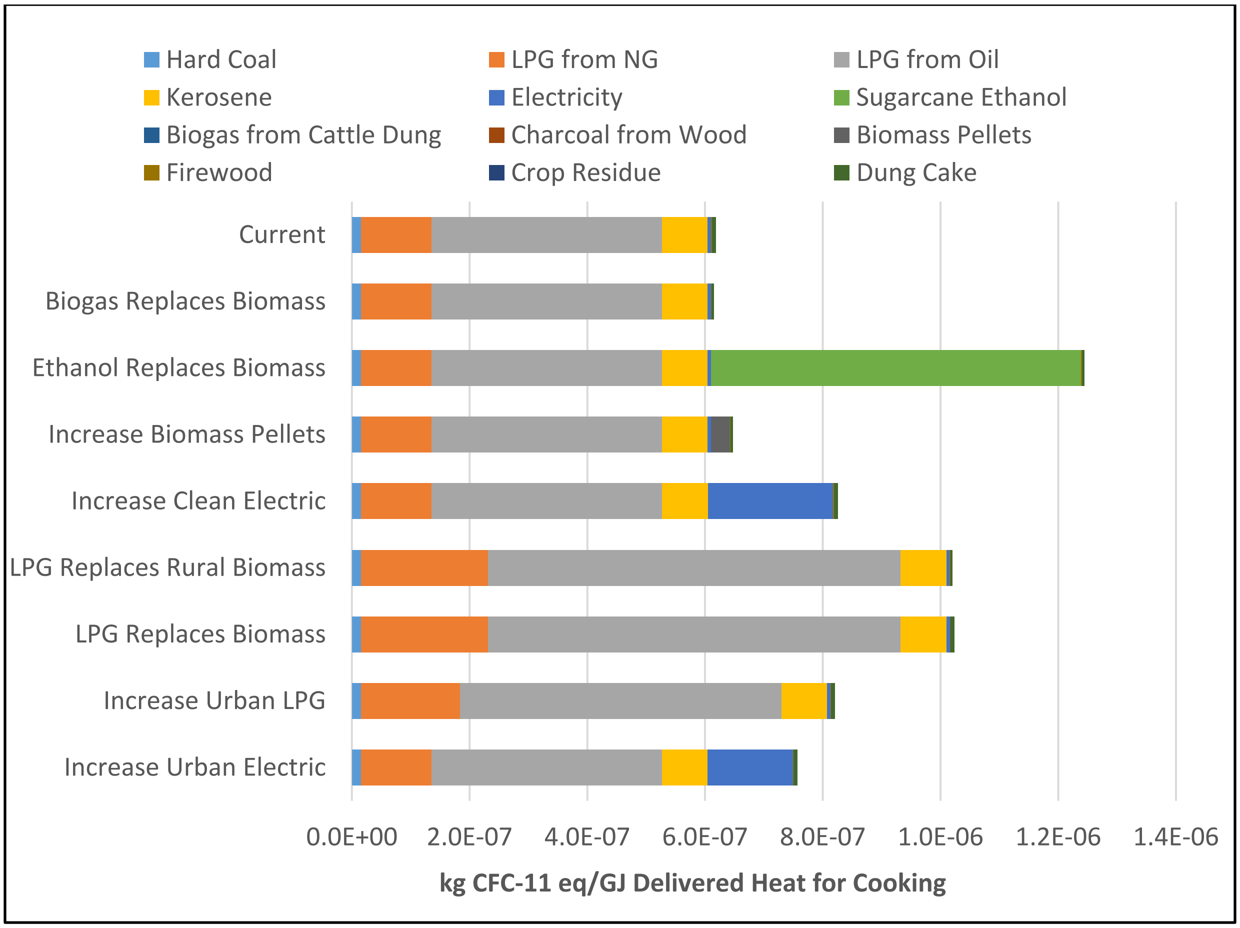


Figure 3-19. Ozone Depletion Potential for Current and Future Fuel Mix Scenarios in India

3.2.10 Black Carbon and Short-Lived Climate Pollutants

The summary impacts of fuel scenarios on the BC impact category are displayed in Figure 3-20. All of the alternative scenarios show a reduced impact compared to the current cook fuel scenario. Scenarios that replace the burning of biomass with fossil fuel alternatives that tend to have higher thermal stove efficiencies reduces emissions contributing to this impact category. Across all of the study scenarios firewood, dung cake, and to a lesser extent crop residues, account for the majority of impacts. Dung cake in particular, due to its poor thermal efficiency, is responsible for a disproportionate share of the impacts considering it accounts for 10.6% or less of the fuel mix in all of the study scenarios.

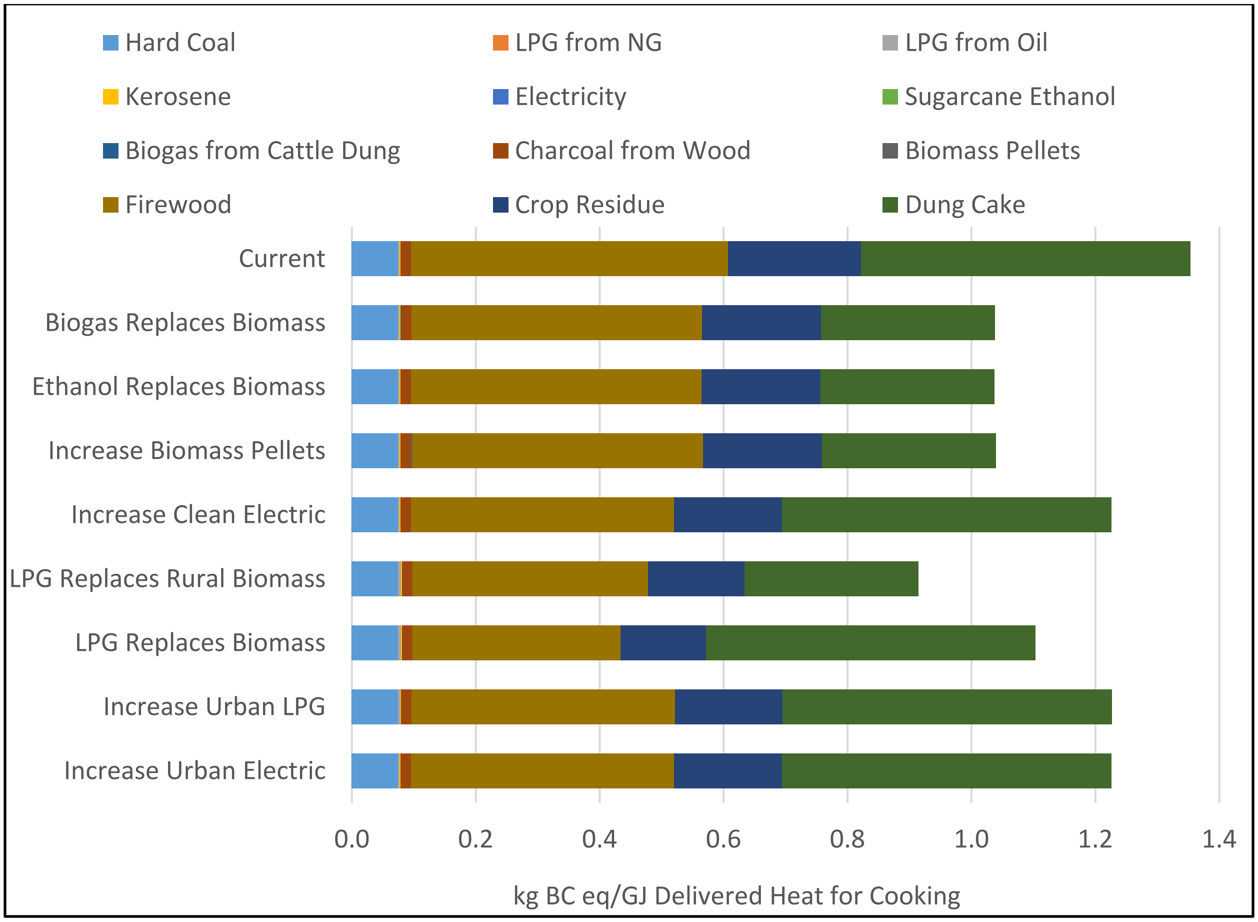


Figure 3-20. Black Carbon and Short-Lived Climate Pollutant Impacts for Current and Future Fuel Mix Scenarios in India

3.2.11 Relative Impacts of Current and Cleaner Electrical Grid Scenarios in India

Two scenarios were developed that featured an increase in the use of electrical energy as a cooking fuel. One of these scenarios was developed using the current national grid energy mix as it exists in India. The second scenario is based on projections regarding the introduction of a cleaner mix of fuels into the Indian national grid. The result of these grid scenarios for each impact category are depicted in the previous sections. Figure 3-21 and Figure 3-22 display the relative environmental impacts of each grid per GJ of delivered heat, with each figure presenting results for five of the impact categories. The fuel mix for each of the grids is displayed in an earlier section (Table 2-3). In the clean electric grid scenario, a fraction of coal-fired generation is replaced with hydropower, natural gas, wind, and nuclear energy. These substitutions yield an improvement in environmental performance in seven of the ten impact categories. These improvements fall within the range of between 4 and 18%. Ozone depletion, black carbon, and water depletion impacts are each higher in the cleaner grid scenario by 32%, 21%, and 20%, respectively. The increase in water depletion impacts is due to evaporative losses from reservoirs resulting from the increase in hydroelectric power. The increase in black carbon impacts associated with the cleaner electricity grid scenario can be traced to the decreased contribution of coal in the cleaner electricity mix. The sulfur based particulate emissions associated with coal exhibit a short-term cooling effect, thereby decreasing black carbon impacts, relative to the clean electricity scenario. Coal also has a relatively low ozone depletion potential when compared to the liquid fossil fuels, which explains the increase in ozone depletion impacts associated with the clean electricity mix scenario.

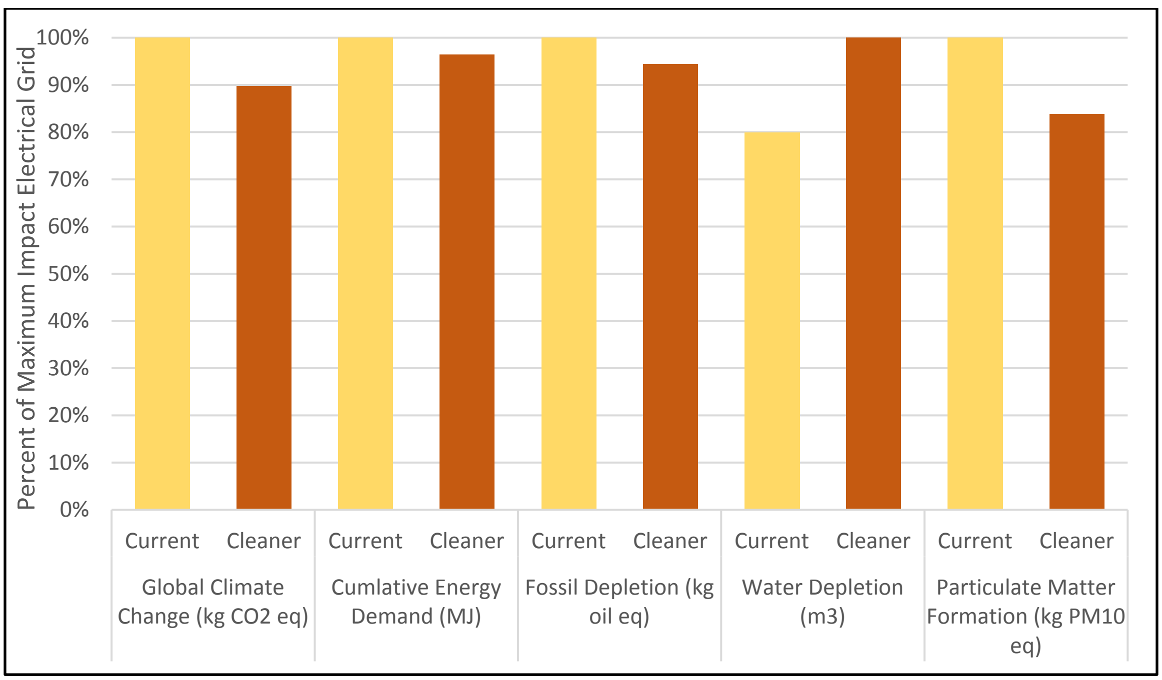


Figure 3-21. Relative Global Climate Change, Cumulate Energy Demand, Fossil Depletion, Water Depletion, and Particulate Matter Formation Impacts of Study Electricity Grids in India

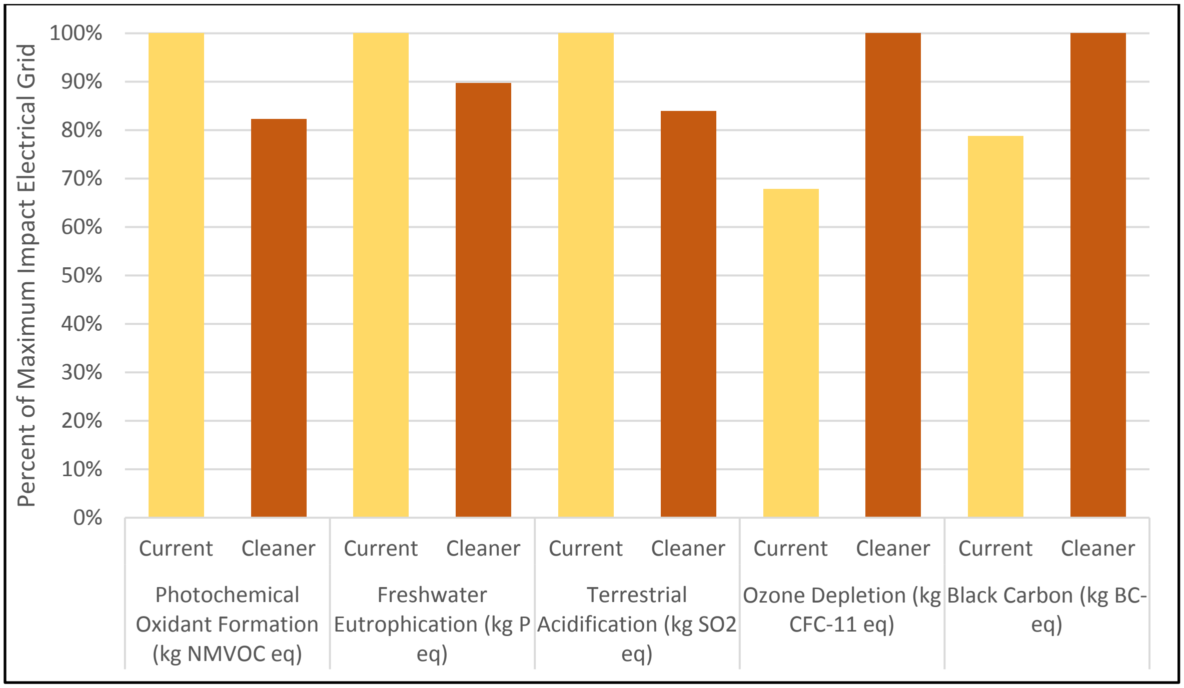


Figure 3-22. Relative Photochemical Oxidant Formation, Eutrophication, Acidification, Ozone Depletion, and Black Carbon Impacts of Study Electricity Grids in India

3.3 Summary Tables for Fuel and Fuel Scenarios in India

This section presents summary tables that allow an easier (simplified) visual side-by-side comparison of individual fuels and fuel scenarios across impact categories. In each indicator column, the results are assigned numbers, with lower numbers and green coloration associated with lower (better) relative environmental results. The numbering and color coding should not be interpreted as indications that differences between fuels and fuels scenarios are statistically significant. A binary interpretation as comparatively better systems (green) and relatively worse systems (yellow) is more appropriate. Additionally, the relative importance of individual impact categories themselves is subjective and should be considered carefully when interpreting the results or drawing conclusions about the performance of one fuel or fuel scenario over another.

Despite these cautionary statements and the trade-offs that exist between impact categories, Table 3-1 does show some notable trends across the considered fuels. Biogas consistently emerges as a low-impact fuel across the majority of impact categories. None of the other fuels exhibit such consistently favorable results across all indicators. In contrast, dung cake and hard coal are often found on the less favorable end of environmental performance.

Table 3-1. Ranked Performance of Fuels by Impact Category in India

	Climate Change	Cumulative Energy Demand	Fossil Depletion	Water Depletion	Particulate Matter Formation	Photochemical Oxidant Formation	Freshwater Eutrophication	Terrestrial Acidification	Ozone Depletion	Black Carbon
Hard Coal	12	12	12	6	10	9	3	11	7	10
LPG from NG	7	1	8	7	2	4	2	4	10	3
LPG from CO	8	4	9	8	3	5	4	5	9	5
Kerosene	5	5	10	10	6	6	5	6	11	7
Electricity	9	6	11	12	7	7	6	12	8	1
Sugarcane Ethanol	2	7	7	11	4	3	8	8	12	2
Biogas from Dung	1	2	1	4	1	1	1	1	1	4
Charcoal from Wood	11	10	4	3	11	11	11	2	4	11
Biomass Pellets	4	3	6	9	5	2	7	3	6	6
Firewood	10	8	2	1	8	8	9	7	2	8
Crop Residue	3	9	3	2	9	10	10	9	3	9
Dung Cake	6	11	5	5	12	12	12	10	5	12

A summary table presenting the relative life cycle environmental results for each fuel scenario by impact category is included below in Table 3-2. Scenarios are numbered from 1 through 9 across rows corresponding to the magnitude of their relative results from lowest (best) to highest (worst) in each environmental impact category. Scenarios (columns) with more green have comparatively better environmental results than scenarios in columns with more yellow. As described for the previous table on individual fuels, the numerical values lack precision necessary to state that significant differences in life cycle environmental impact results are present between scenarios; therefore, when interpreting results it is more appropriate to use the simplified color scale to identify fuel systems that tend to perform better (green) or worse (yellow) in the categories of interest.

Table 3-2 does indicate a number of notable trends. As in the previous table, the scenario with increased use of biogas has consistently positive environmental results. The current fuel mix scenario, on the other hand, demonstrates relatively higher (worse) performance in seven of the ten impact categories and relatively better performance in the remaining three (fossil fuel, water depletion, and ozone depletion), showing clear trade-offs inherent in the current mix. Other scenarios show more mixed results; however, 'LPG replaces biomass' has generally better environmental performance while the two scenarios with increased use of electricity show consistently higher impact trends. While these tables do not conclusively identify the best and worst options, the tables indicate where further analysis of model sensitivity and significance should be pursued.

Table 3-2. Ranked Performance of Fuel Scenarios by Impact Category in India

	Increase Urban Electric	Increase Urban LPG	LPG Replaces Biomass	LPG Replaces Rural Biomass	Increase Clean Electric	Increase Biomass Pellets	Ethanol Replaces Biomass	Biogas Replaces Biomass	Current
Climate Change	8	6	1	4	7	5	3	2	9
Cumulative Energy	8	5	2	1	7	4	6	3	9
Fossil Depletion	7	5	9	8	6	3	4	1	2
Water Depletion	8	3	6	5	9	4	7	2	1
Particulate Matter	8	6	5	1	7	4	3	2	9
Photochemical Oxidant Formation	8	6	5	1	7	3	4	2	9
Eutrophication	8	6	5	1	7	3	4	2	9
Acidification	9	5	4	2	8	3	6	1	7
Ozone Depletion	4	5	8	7	6	3	9	1	2
Black Carbon and Short-Lived Climate Pollutants	6	8	5	1	6	4	2	3	9

4. LIFE CYCLE ASSESSMENT RESULTS FOR CHINA

This section presents cookstove fuel LCA results for China first by individual cooking fuel type, followed by fuel mix scenario.

4.1 Results for China by Cooking Fuel Type

The following 10 sections provide the results analysis of the LCI and LCIA categories for the individual fuels used within China. Results are provided in graphical format in this section and companion tables for each figure are provided in Appendix B: Detailed LCA Results Tables.

4.1.1 Global Climate Change Potential

Figure 4-1 displays the GCCP results for China for each cookstove fuel included in this study. Fossil fuel GCCP impacts are dominated by combustion emissions in the cookstove use stage. Coal has the highest impacts, since it is derived from non-renewable carbon and the thermal efficiency of coal stoves (27.2%-37.1%) is relatively low compared to stoves used for the other fossil fuel options (e.g., natural gas stove efficiency is 44.8%-45.9%). Coal is widely used and transported long distances in China, resulting in a notable contribution of GHGs from the distribution life cycle stage. Electricity in China is derived primarily from coal (79%) and hydroelectric facilities (14.8%), which is the primary reason electricity impacts are similar to but slightly lower than coal. For consistency with other fuels, the fuel combustion emissions associated with electricity generation are shown in the use stage here, although electricity-related fuel combustion emissions do not occur at the household level. Crop residues are derived from renewable biomass that removed CO_2 from the atmosphere during growth; therefore, the CO_2 emissions released from combustion of these residues are considered carbon neutral. Impacts for the renewable crop residue fuels during the use phase are driven by nitrous oxide and methane emissions during cookstove use.

Based on the trend in forest area in China and the annual generation of biomass per hectare, 57% of the firewood required for cooking can be sustainably sourced; therefore, the combustion emissions for the non-renewable 43% of wood are not considered carbon-neutral. This adjustment is also applied to the portion of biomass pellets derived from wood.

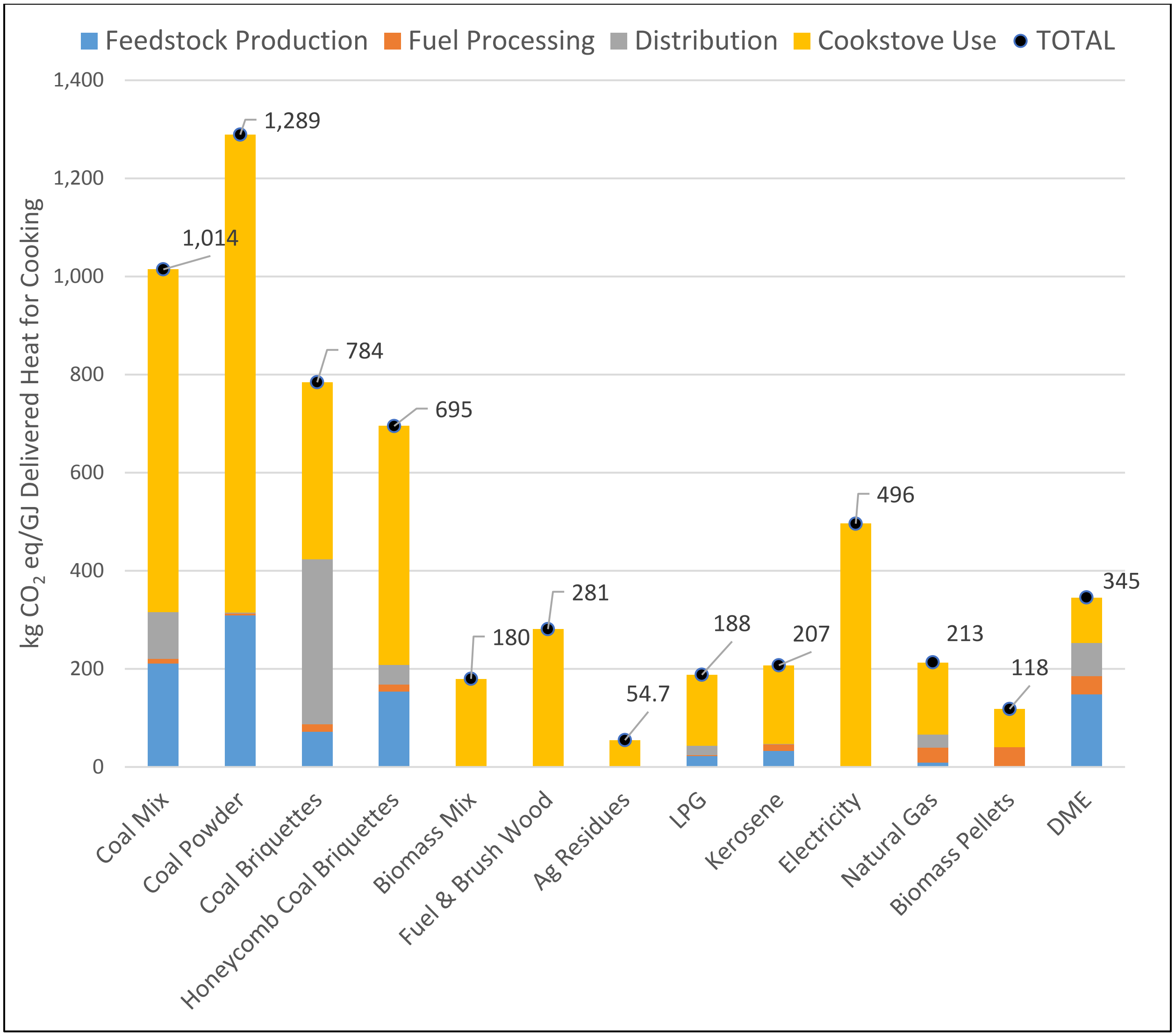


Figure 4-1. Global Climate Change Potential Impacts of Cooking Fuels per GJ of Delivered Heat for China

4.1.2 Cumulative Energy Demand

Figure 4-2 displays the CED results for China for each cookstove fuel included in this study. Energy demand tracks all energy inputs across the life cycle of the fuel, with combustion energy impacts shown at the point of use of the relevant fuel.

The cumulative energy demand results are largely a function of the fuel heating value and thermal efficiency of the fuel and stove combination. Stoves with higher efficiencies (e.g., used for LPG, kerosene, natural gas, DME, and biomass pellets) have a lower cumulative energy demand overall, because more of the heating value of the fuel is converted into useful cooking energy and therefore less fuel must be produced, transported, and burned to deliver the same amount of cooking energy.

A number of observations can be made regarding energy results for the various types of fuels. The biomass pellets have a lower cumulative energy demand than traditional wood or crop residues. Biomass pellets typically have a lower moisture content, greater energy content, and greater surface area than the traditional solid biomass, which allows the fuel to combust more efficiently. It is also more common to see improved cookstoves, which have higher stove thermal efficiencies, used in combination with biomass pellets in China.

Overall, liquid and gas fuels, which includes piped natural gas, as well as processed solid biomass fuels that do not require additional combustion of solid fuel for processing (e.g., wood pellets) are the fuels that show the lowest overall cumulative energy demand impacts. Hard coal shows the highest overall cumulative energy demand due to the energy required for coal mining and distribution and the low coal stove thermal efficiency. While DME is produced from coal feedstock via gasification, lower cumulative energy demand impacts are seen for DME as compared to coal due to its use in more efficient gas stoves.

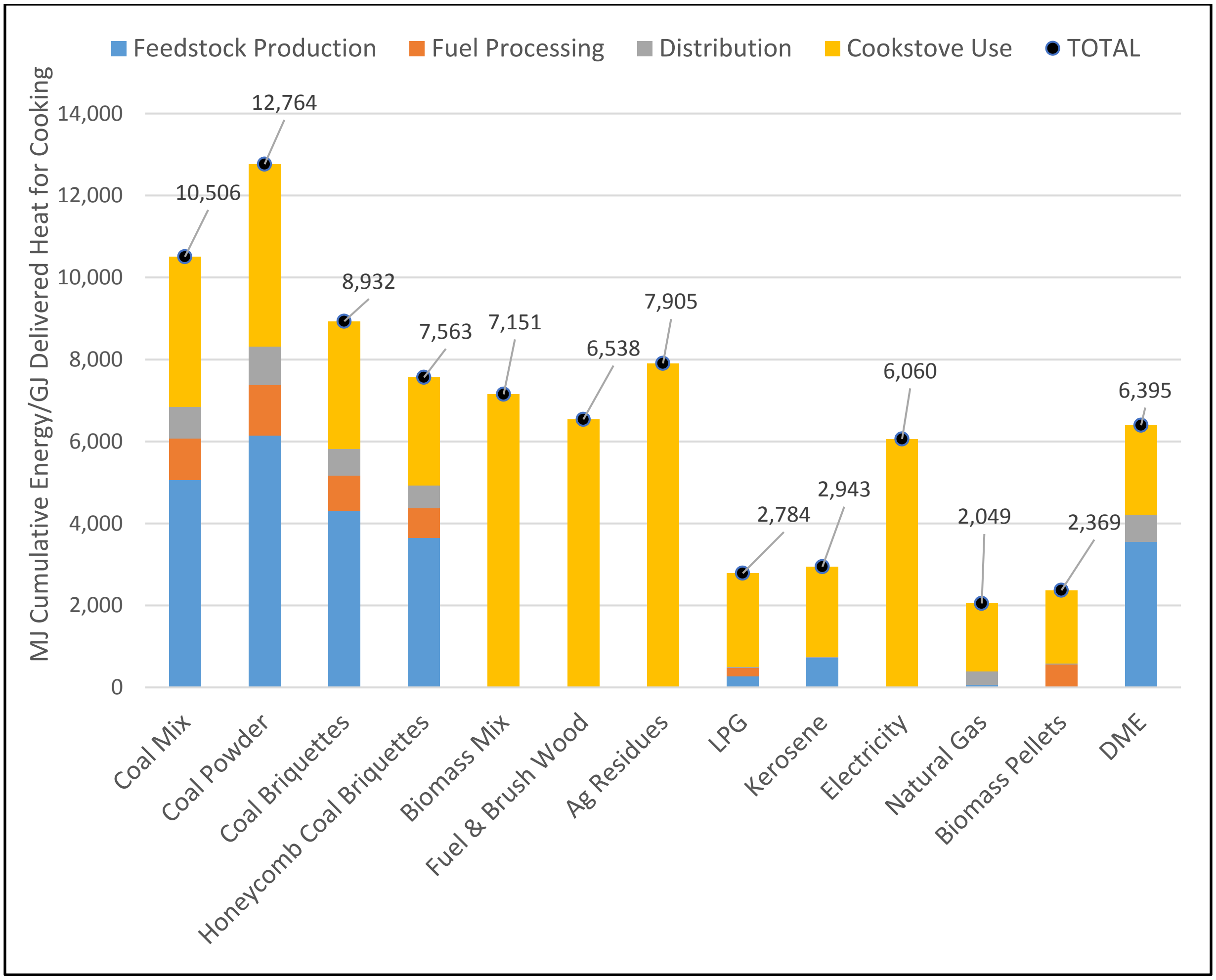


Figure 4-2. Cookstove Fuel Cumulative Energy Demand Impacts for China

4.1.3 *Fossil Depletion*

Figure 4-3 displays the fossil depletion results for China for each cookstove fuel included in this study. All fuels are normalized to the unit, kg oil equivalents, based on the heating value of the fossil fuel relative to oil. The fossil depletion associated with traditional biomass fuels and biogas is negligible, as these fuels are not derived from fossil fuel, and collection of these fuels is done manually. Fossil depletion for biomass pellets is associated with electricity usage for pelletization and some transport. Fossil depletion impacts are highest for electricity (primarily fossil-fuel derived), coal, DME (from coal gas), LPG, kerosene and natural gas, as these sources of cooking energy rely on fossil fuels. The greatest impacts are seen for coal. When compared to the liquid fossil fuels, coal demonstrates both a lower heating value (MJ/kg) and a lower stove thermal efficiency (~22%), which leads to more coal being burnt to realize the same amount of cooking energy.

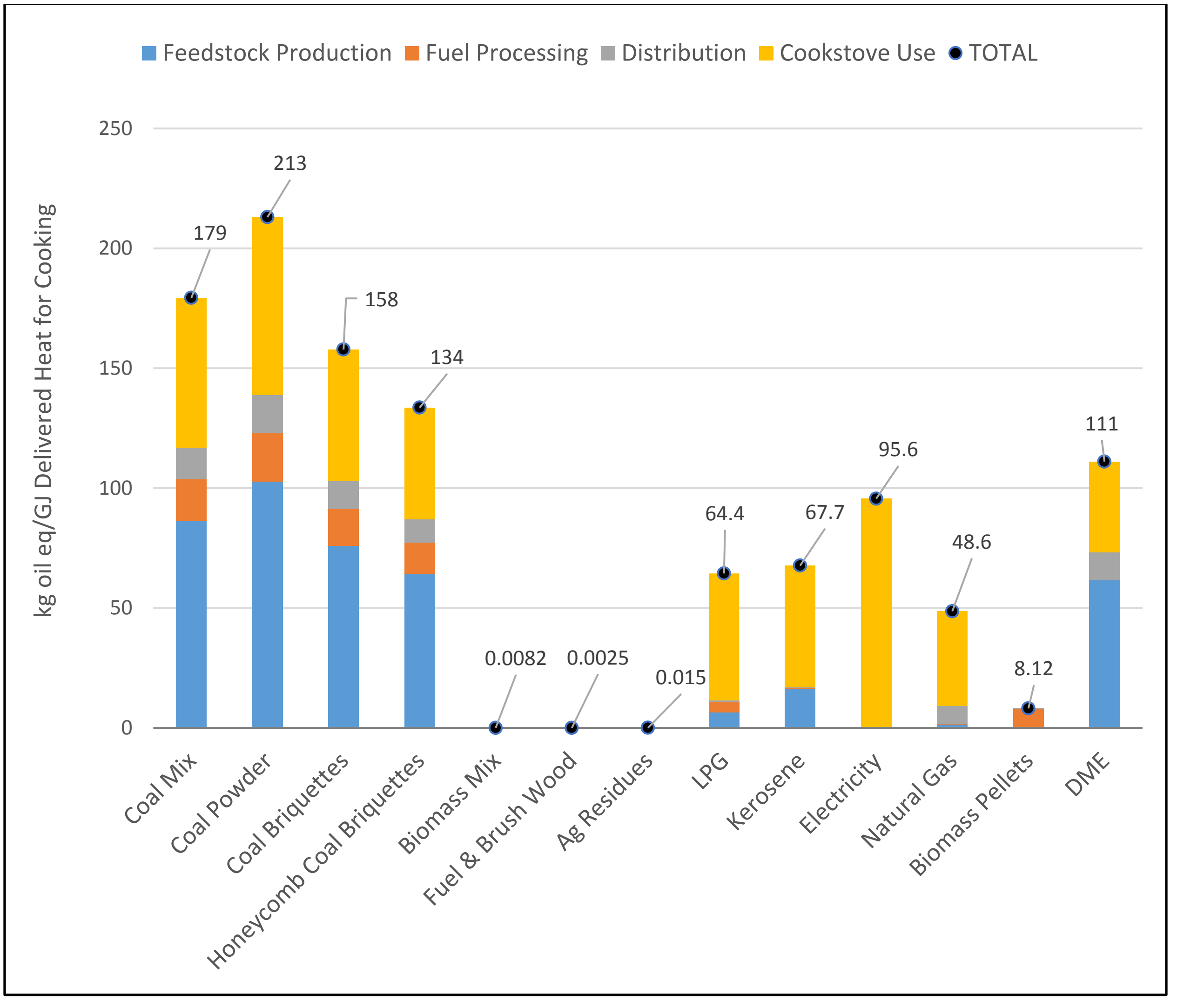


Figure 4-3. Cookstove Fuel Fossil Depletion Impacts for China

4.1.4 Water Depletion

Figure 4-4 displays the water depletion results for China for each cookstove fuel included in this study. Water may be incorporated in the fuel product, evaporated, or returned to the same or different water body or to land. If the water is returned to the same water body, it is assumed the water is returned at a degraded quality, and therefore is considered consumptive use. Water consumption includes evaporative losses from establishment of hydroelectric dams but does not include the water passing through the turbine, since that water is not removed from its source. The hydropower in the electricity mix drives the overall water depletion impacts. In this case, for simplicity, electricity impacts have been allocated to the use stage of the cooking fuel life cycle. Water depletion associated with fossil fuel use is also due to electricity usage during fuel processing and/or distribution. Water depletion impacts are negligible for the traditional biomass fuels. Because the water content of these fuels comes from the atmosphere as rainfall, the water released back to the atmosphere when the biomass is dried or combusted is not considered consumptive use.

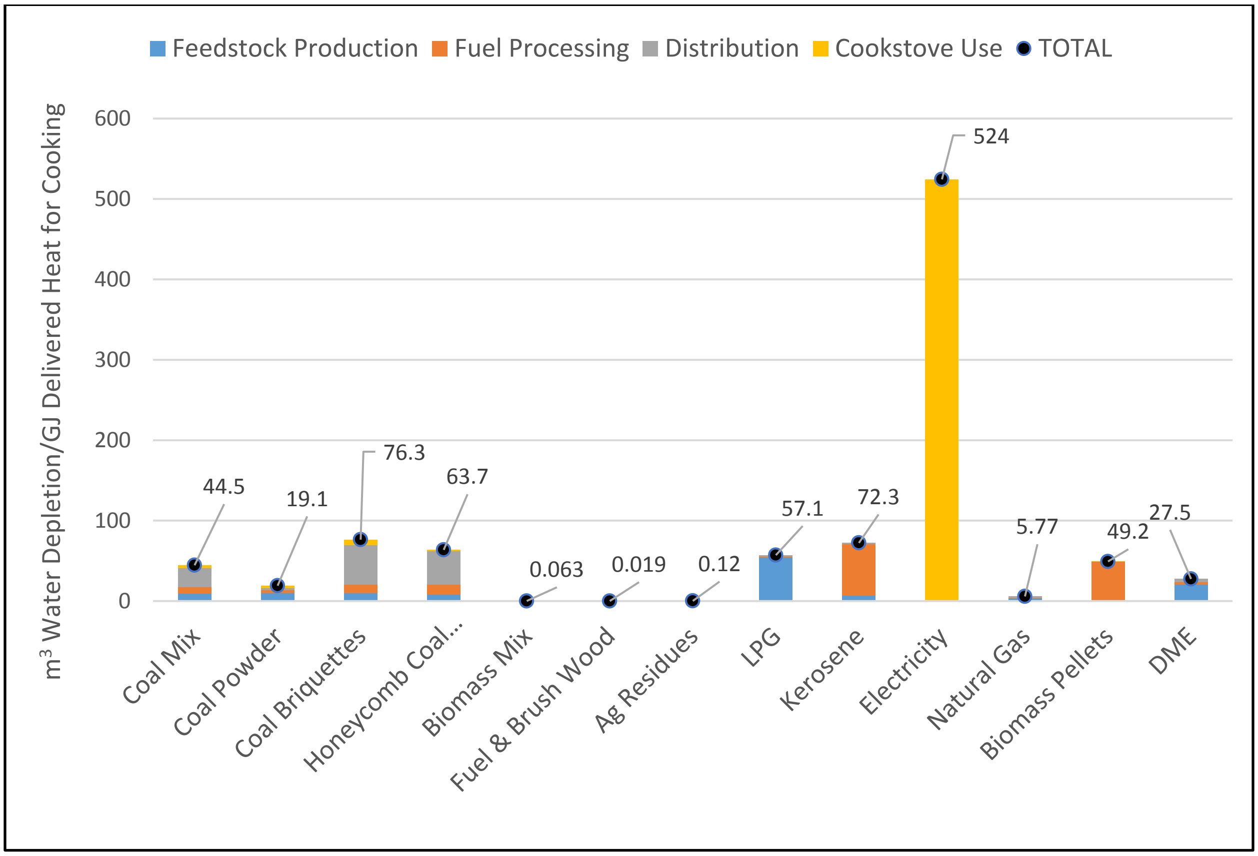


Figure 4-4. Cookstove Fuel Water Depletion Impacts for China

4.1.5 Particulate Matter Formation Potential

Figure 4-5 displays the particulate matter formation results for China for each cookstove fuel included in this study. Most particulate matter formation impacts occur during cookstove use at the household with the exception of electricity, in which case the particulates are emitted at power plants during grid fuels' combustion. Due to the complexity of life cycle stages for the numerous fuels in the electricity grid, all electricity burdens have been allocated to the use phase, although the actual particulate matter emissions for electricity do not occur at the household level. Most of the particulate matter impacts for electricity are derived from the coal mix in the average China electrical grid. At the household level, non-briquette forms of coal and unprocessed biomass fuels lead to the greatest particulate matter formation impacts, with agricultural residues having the highest overall impacts. Advanced liquid fuels as well as biomass pellets have comparably small particulate matter impacts.

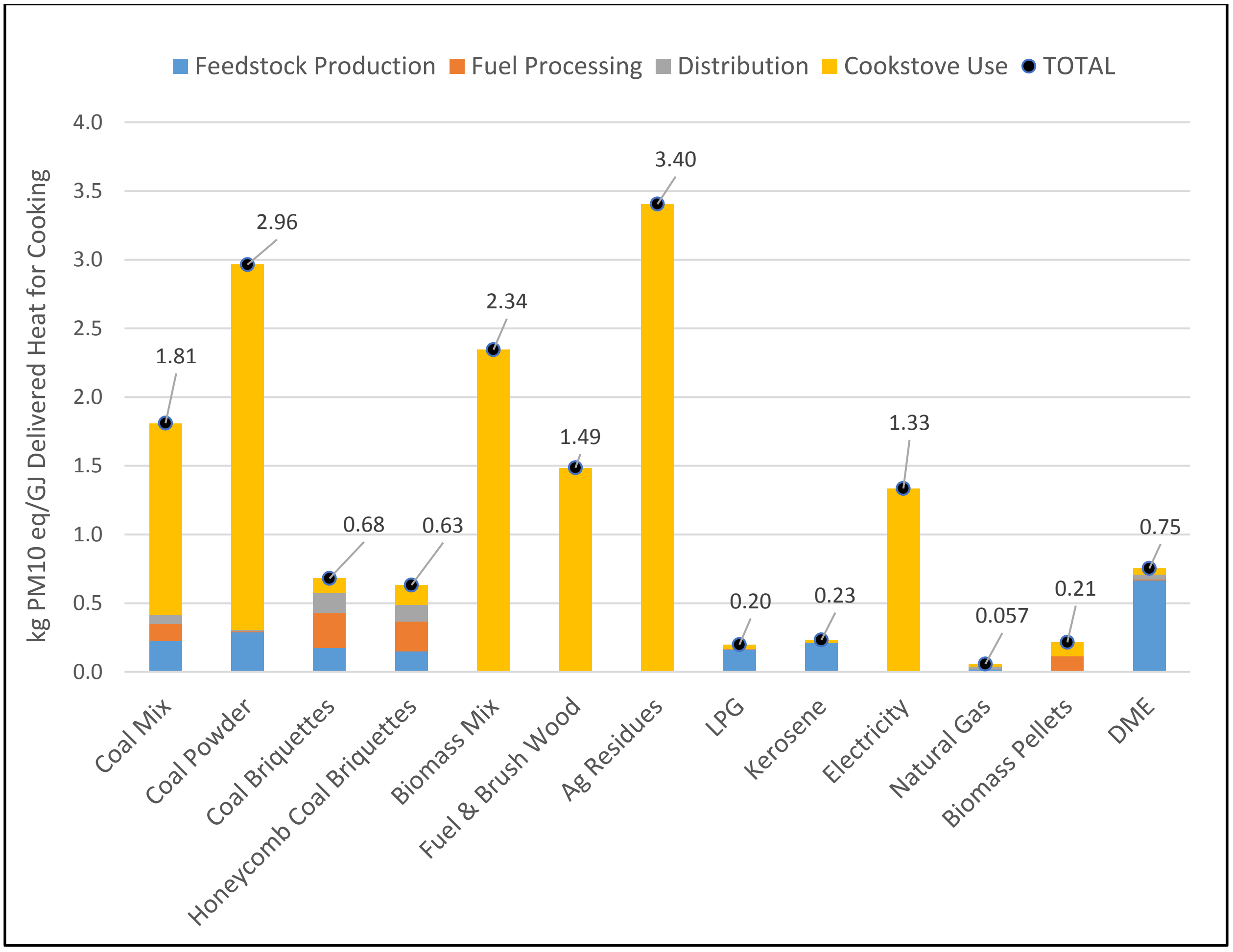


Figure 4-5. Cookstove Fuel Particulate Matter Formation Potential Impacts for China

4.1.6 Photochemical Oxidant Formation Potential

Figure 4-6 displays the photochemical oxidant formation results for China for each cookstove fuel included in this study. Coal-derived fuels and traditional biomass lead to the greatest photochemical formation impacts, with coal powder having the highest overall impacts.

For DME, impacts are driven by the distribution stage resulting from long-distance transport NMVOC emissions of the coal gas from plant to rural consumer via a high pressure pipeline network. Electricity impacts are primarily associated with utilization of hard coal in the grid mix. Electricity impacts are shown in the use stage here for simplicity, although the contributing emissions are not released at the household level. Photochemical oxidant formation impacts are relatively small for the liquid fuels and biomass pellets.

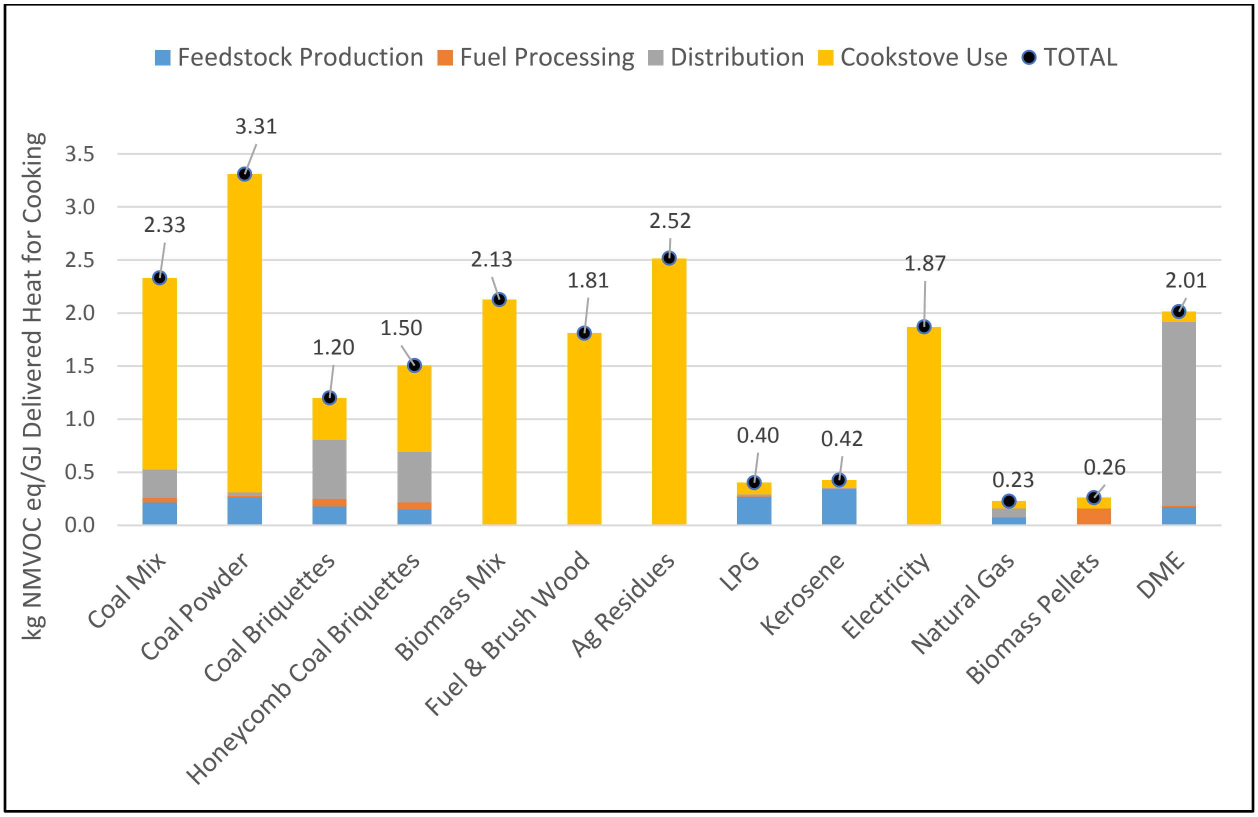


Figure 4-6. Cookstove Fuel Photochemical Oxidant Formation Potential Impacts for China

4.1.7 Freshwater Eutrophication Potential

Figure 4-7 displays the freshwater eutrophication results for China for each cookstove fuel included in this study. Agricultural residues result in the highest eutrophication potential impacts. This is due to the much larger ash quantity produced from these fuels compared to all other fuels. The ash from traditional fuels is assumed to be land applied, which provides a pathway to runoff into water bodies for eventual eutrophication impacts. Ash production and disposal (shown in the use phase) is also the reason that coal-derived fuels have a relatively high eutrophication impact. Impacts from advanced gas fuels and biomass pellets are minimal compared to the coal-derived and traditional biomass fuels. Eutrophication impacts for electricity, primarily associated with utilization of hard coal in the grid mix, are shown in the use stage here for simplicity; however, impacts do not occur at the household level but rather during extraction and beneficiation of the coal resources.

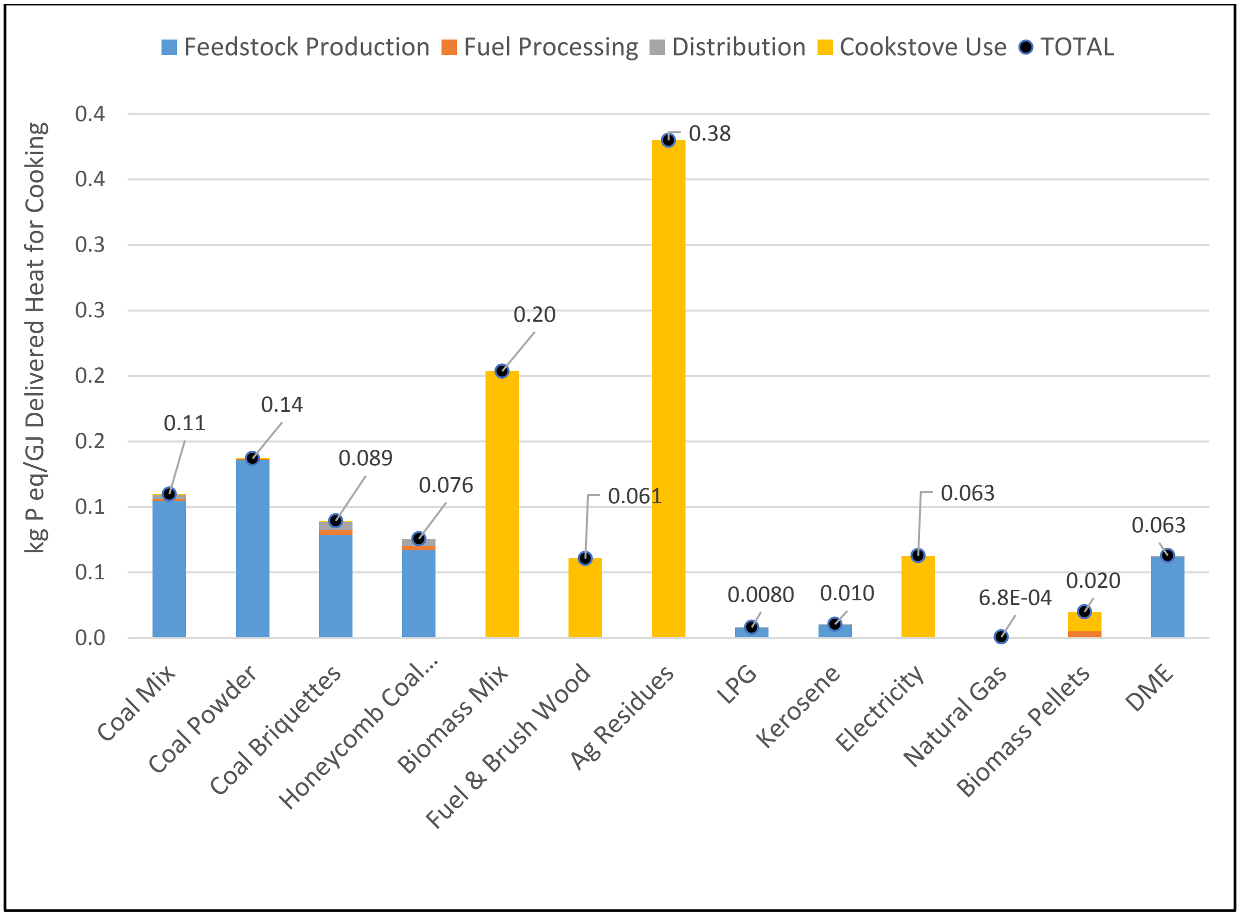


Figure 4-7. Cookstove Fuel Freshwater Eutrophication Potential Impacts for China

4.1.8 *Terrestrial Acidification Potential*

Figure 4-8 displays the terrestrial acidification results for China for each cookstove fuel included in this study. Acidification impacts are dominated by coal usage, either as a direct fuel or as an input to electricity generation. Sulfur dioxide emissions from coal and coal-derived fuels are notably higher than sulfur dioxide emissions from combustion of other fuels. Coal briquette results are lower than coal mix and coal powder, assuming the same sulfur content. Results are lower for coal briquettes because of their higher heating values and stove efficiencies relative to other coal types, so that less coal must be burned per GJ of cooking energy. Traditional biomass fuels and liquid fuels have low acidification impacts. The lowest overall acidification impacts are seen for natural gas.

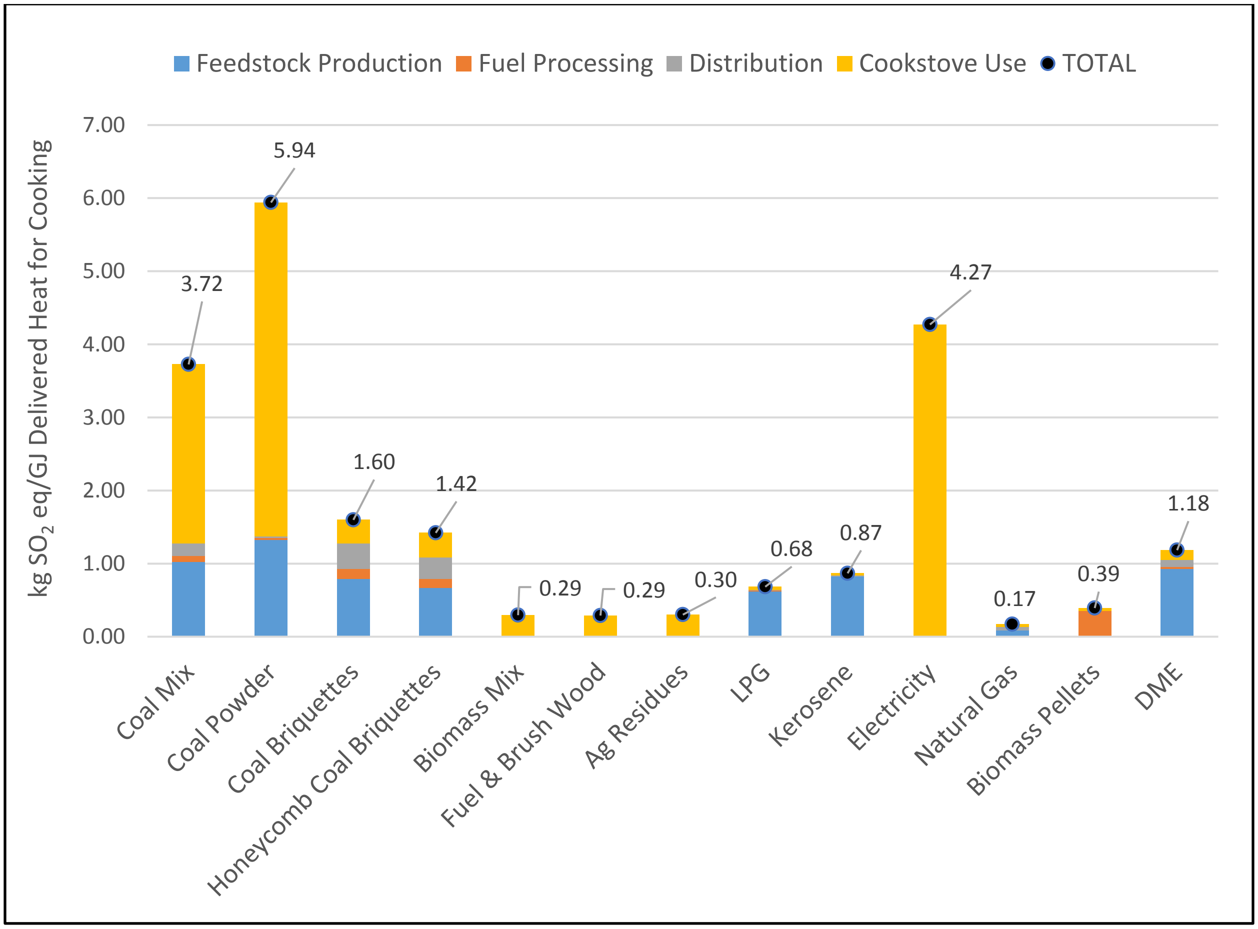


Figure 4-8. Cookstove Fuel Terrestrial Acidification Potential Impacts for China

4.1.9 Ozone Depletion Potential

Figure 4-9 displays the ozone depletion results for China for each cookstove fuel included in this study. Ozone depletion impacts are greatest for the fossil fuels. For fossil-derived fuels, the impacts generally come from halon 1301 or hydrochlorofluorocarbon (HCFC)-22 emissions during feedstock production and fuel processing. Overall, normalized ozone depletion impacts are generally on a much smaller magnitude than other indicators covered, suggesting that less importance should be placed on this indicator when assessing fuel options.

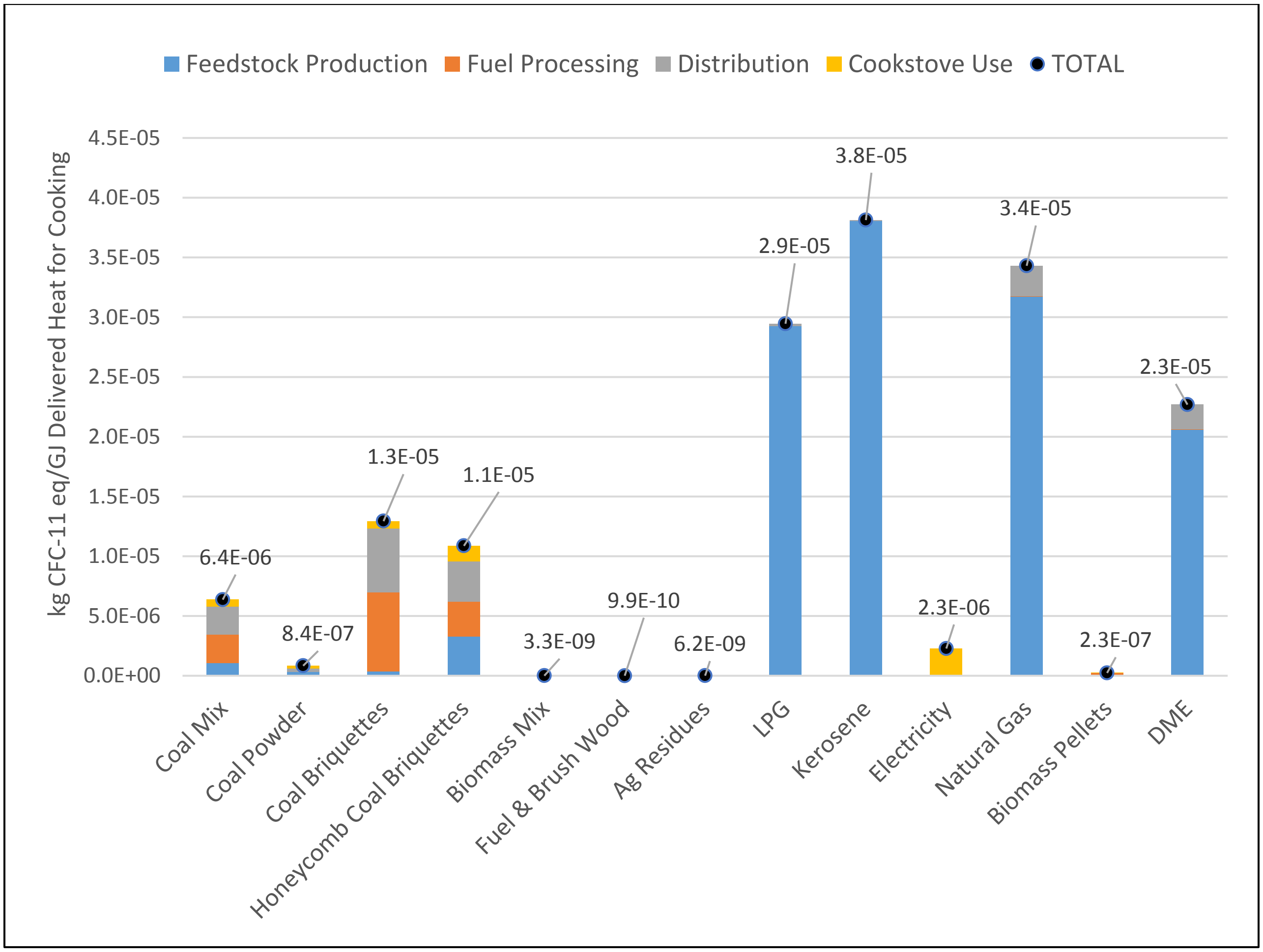


Figure 4-9. Cookstove Fuel Ozone Depletion Potential Impacts for China

4.1.10 Black Carbon and Short-Lived Climate Pollutants

Figure 4-10 displays the black carbon results for China for each cookstove fuel included in this study. Black carbon impacts are greatest for the biomass based fuels, especially agricultural residues. The increased thermal efficiency associated with the use of pelletized biomass significantly reduces impacts in this category. Relatively clean burning fossil fuels with high sulfur contents such as LPG and kerosene and electricity (largely derived from coal) have net negative black carbon impacts due to the cooling effects of their associated SOx emissions.

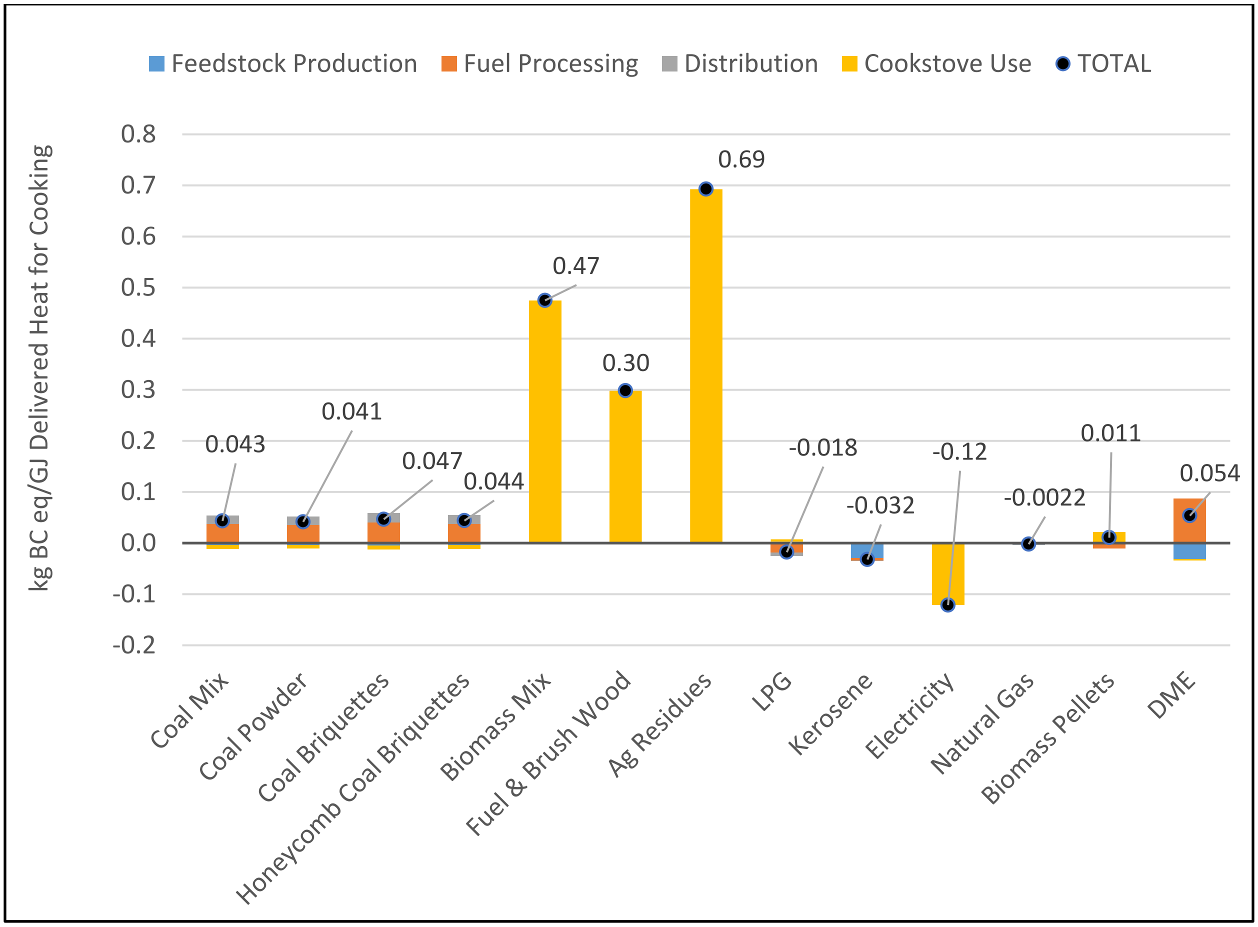


Figure 4-10. Cookstove Fuel Black Carbon and Short-Lived Climate Pollutant Impacts for China

4.2 Results for China by Baseline and Potential Scenarios

Given the magnitude of impacts resulting from the use of cookstoves on both the environment and human health it is important to consider how future changes in the cookstove fuel mix in China might affect cumulative life cycle impacts associated with cooking fuels. Eight potential fuel use scenarios were developed in order to explore how impacts in each of the ten studied environmental impact categories may change in the future. Table 1-7 provides a list of full scenario names and maps them to the abbreviated scenario names, which are referred to both in text and figures within this section.

4.2.1 Global Climate Change Potential

Figure 4-11 depicts the effects of various future fuel mix scenarios on GCCP. In general, future scenario results show an improvement in climate change impacts over those generated by the current fuel mix. The scenario in which 'LPG Replaces Coal' yields the greatest climate change benefit. Conversely, if LPG is used to replace biomass, impacts in this category increase slightly. Increasing the use of biomass pellets and using a cleaner electricity grid are also scenarios that result in lower greenhouse gas emissions. Despite the assumption that biogenic carbon is neutral in respect to global warming potential, biomass fuels are still seen to contribute to this impact category due to the effects of land use change, use of non-renewable wood, and the emission of carbon monoxide and dinitrogen monoxide.

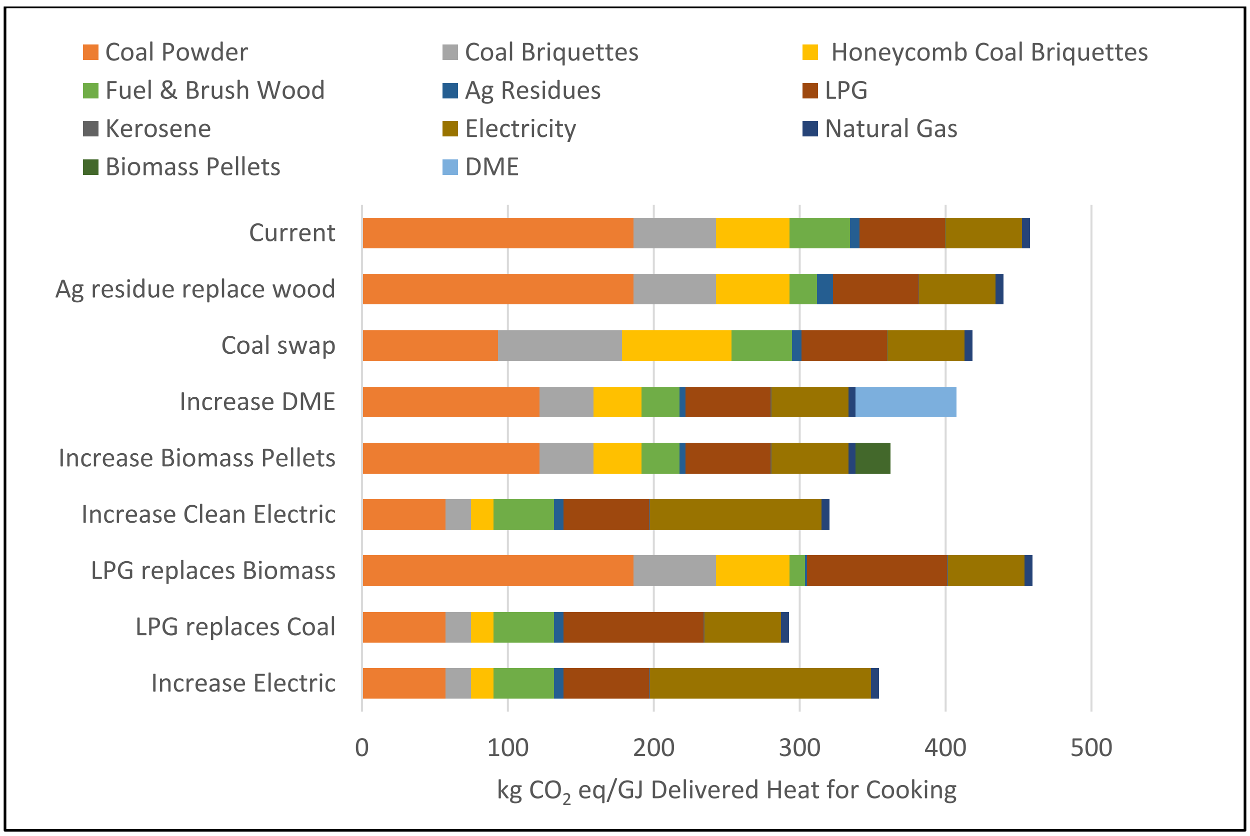


Figure 4-11. Global Climate Change Potential Impacts for Current and Future Fuel Mix Scenarios in China

4.2.2 Cumulative Energy Demand

Figure 4-12 depicts the results of potential future cookstove fuel mix scenarios on impact results for CED. Seven of the eight future scenarios lead to a decrease in cumulative energy demand over the current scenario. The Ag residue scenario, where crop residues are utilized to replace fuel and brush wood, leads to a slight increase in overall cumulative energy demand. Replacing rural coal use with LPG yields the greatest decrease in CED. The use of biomass pellets in place of coal or non-pelletized biomass also yields marked improvement in this impact category. In all three cases stove efficiencies change with the shifting use of fuel feedstock, which affects energy demand, and thus impacts in this category.

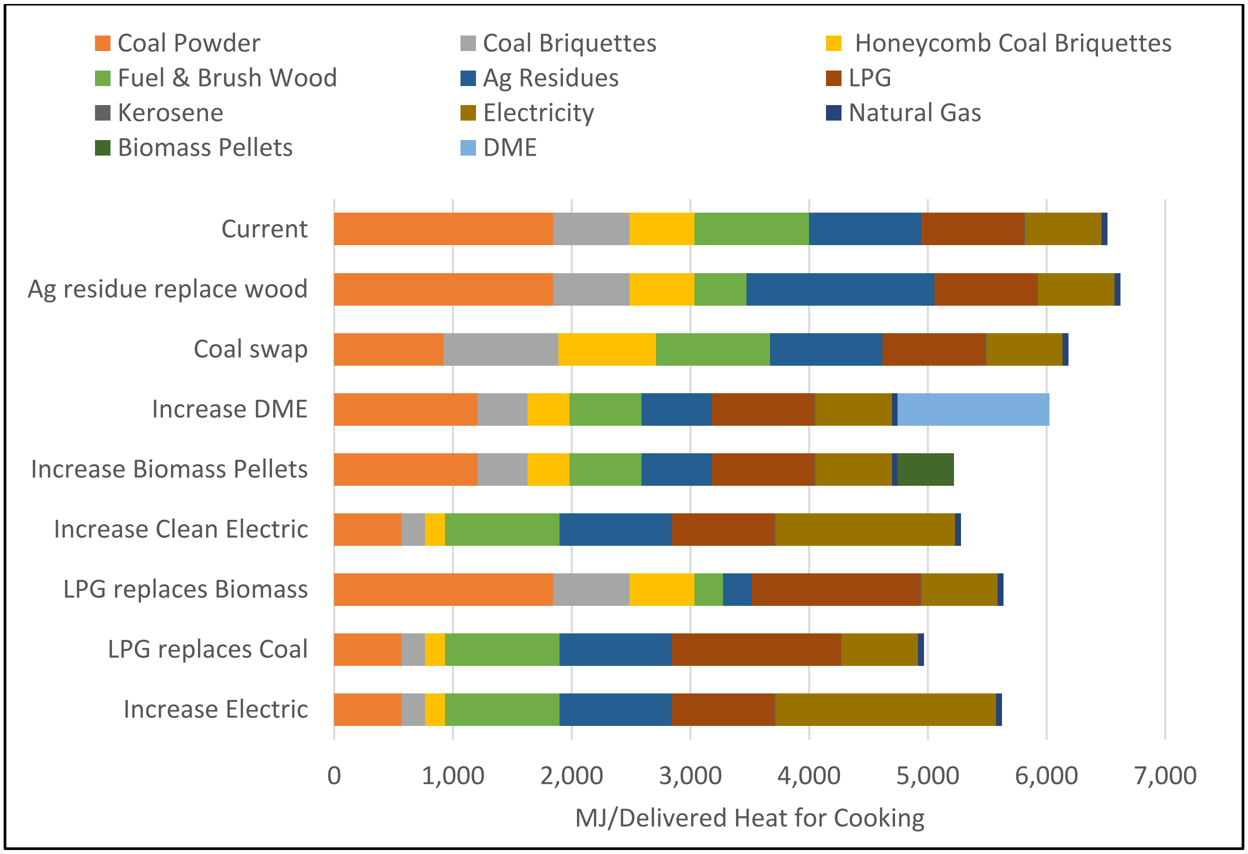


Figure 4-12. Cumulative Energy Demand for Current and Future Fuel Mix Scenarios in China

4.2.3 Fossil Depletion

Figure 4-13 provides summary results showing how potential future shifts in cookstove fuel mix affect the demand for fossil fuel resources. The largest decrease in fossil fuel use among the study scenarios is realized by replacing coal with LPG as a cookstove fuel. The clean electricity scenario also reduces fossil fuel use significantly. In this scenario, the corresponding increases in stove efficiency that accompany many of the fuel shifts are a major contributor to the decrease in fuel use. Conversely, replacing biomass with either LPG or DME fuel demonstrates the expected increase in fossil depletion due to the nature of the fuels themselves. In both of these scenarios the increase in stove efficiency is not enough to overcome the fact that biogenic feedstock is replaced with fossil fuel based substitutes.

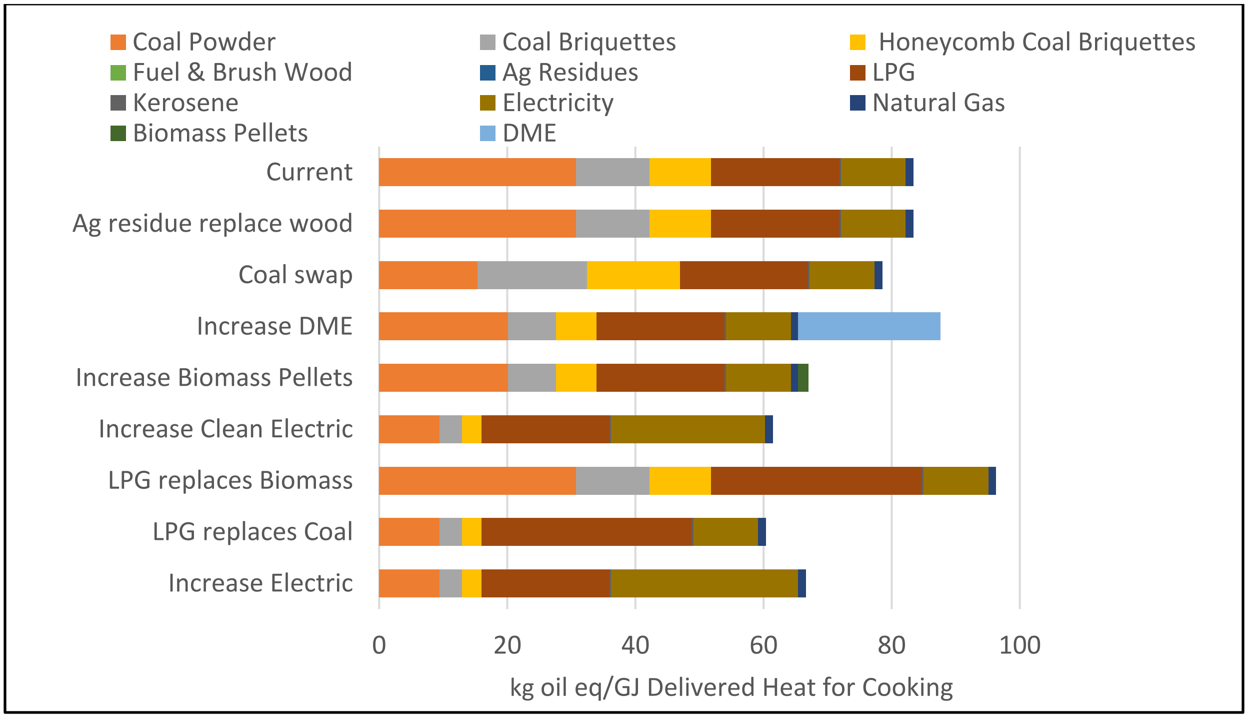


Figure 4-13. Fossil Depletion for Current and Future Fuel Mix Scenarios in China

4.2.4 Water Depletion

Figure 4-14 shows the effects of future cookstove fuel mix scenarios on the water depletion impact category. Water depletion increases dramatically in both scenarios where electrical energy increases as a cooking fuel. Only slight differences in water demand are observed between the clean and current electrical grid, with the cleaner grid demanding slightly less water use. Water depletion impacts in the electricity scenarios are driven by evaporative losses associated with hydroelectric power. Current and clean Chinese grid fuel mixes are displayed in Table 2-4. All other scenarios produce water depletion impacts in a relatively tight range (87-98 m^3) per GJ of delivered cooking energy. In general, electricity is the predominant contributing fuel to results in this impact category for all fuel mix scenarios evaluated.

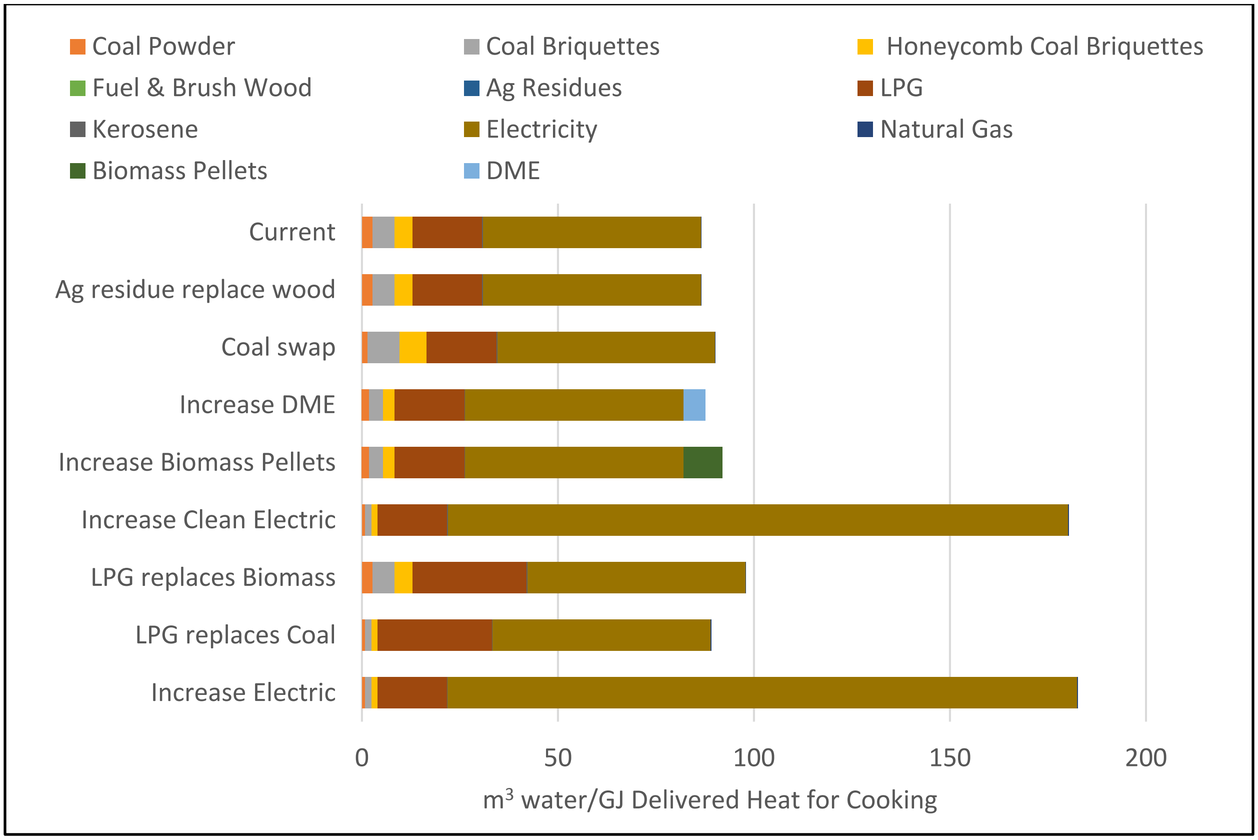


Figure 4-14. Water Depletion Impacts for Current and Future Fuel Mix Scenarios in China

4.2.5 Particulate Matter Formation Potential

The effects of various future fuel mix scenarios on particulate matter formation potential are displayed in Figure 4-15. The Ag residue scenario is the only study scenario that generates higher particulate matter impacts than does the current scenario. It is also the only scenario where the increased cookstove fuel is used in a cookstove with a lower thermal efficiency. Biomass, coal, and electricity all contribute significantly to the results in this impact category. LPG can be seen to have a relatively low contribution to this impact category despite its consistently high presence in the fuel mix. As a result of these factors the scenario that yields the lowest particulate matter impact is the one in which it is assumed that LPG replaces biomass. A strategy which increases the use of pelletized biomass also positively affects impact scores in this category.

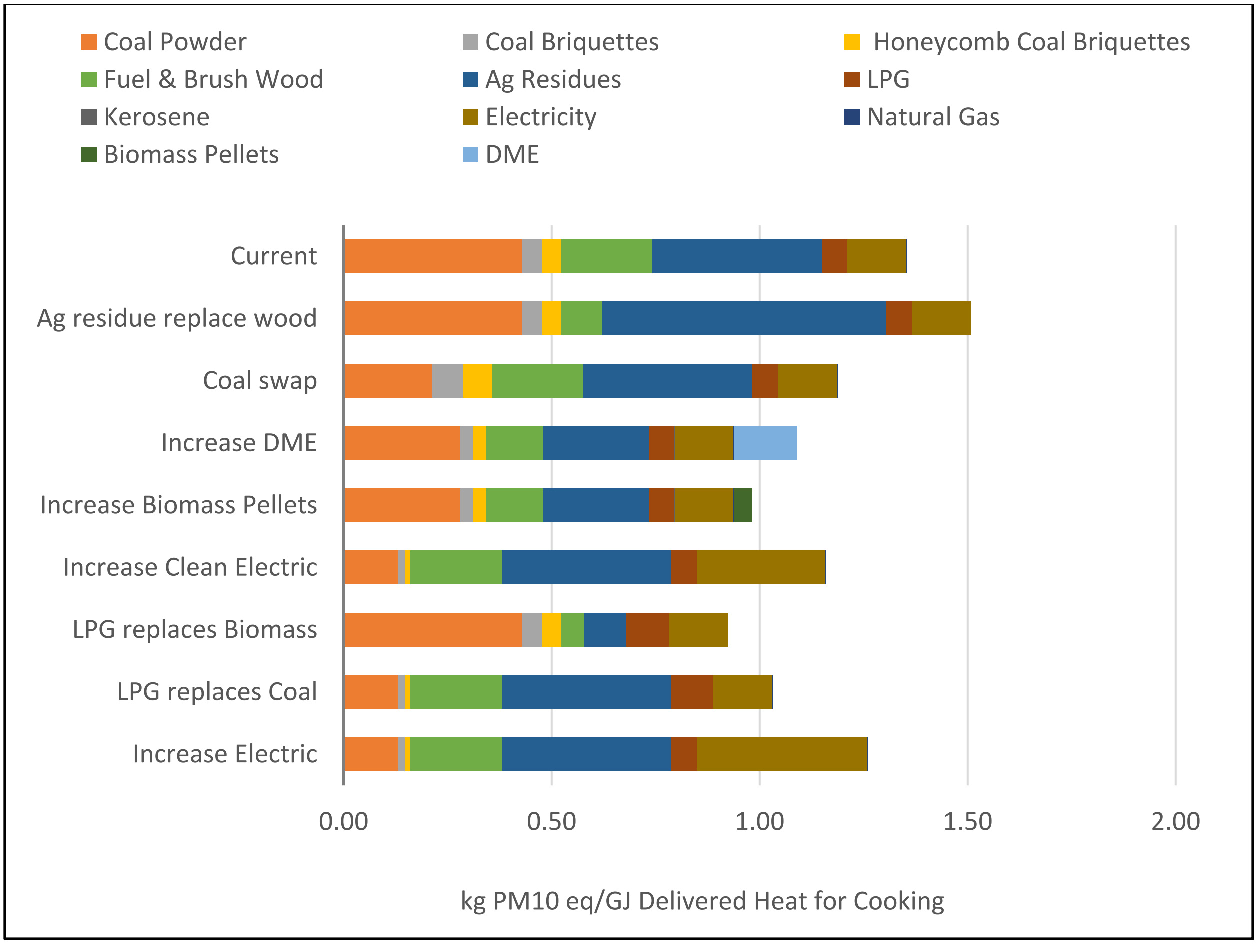


Figure 4-15. Particulate Matter Formation Potential for Current and Future Fuel Mix Scenarios in China

4.2.6 Photochemical Oxidant Formation Potential

The influence of potential fuel use scenarios on photochemical oxidant formation potential impact is presented in Figure 4-16. As in the previous section, it can be seen that the replacement of wood with crop residue as a cooking fuel leads to higher impacts in this category, due in part to the lower thermal efficiencies of stoves that burn crop residues. Among the studied scenarios the replacement of biomass stoves with those utilizing LPG yield the most dramatic decrease in photochemical oxidation impacts. Increased use of biomass pellets is also an effective means of reducing the impact in this category, due not only to the properties of the fuel but also the corresponding increase in thermal efficiency of the pellet cookstoves.

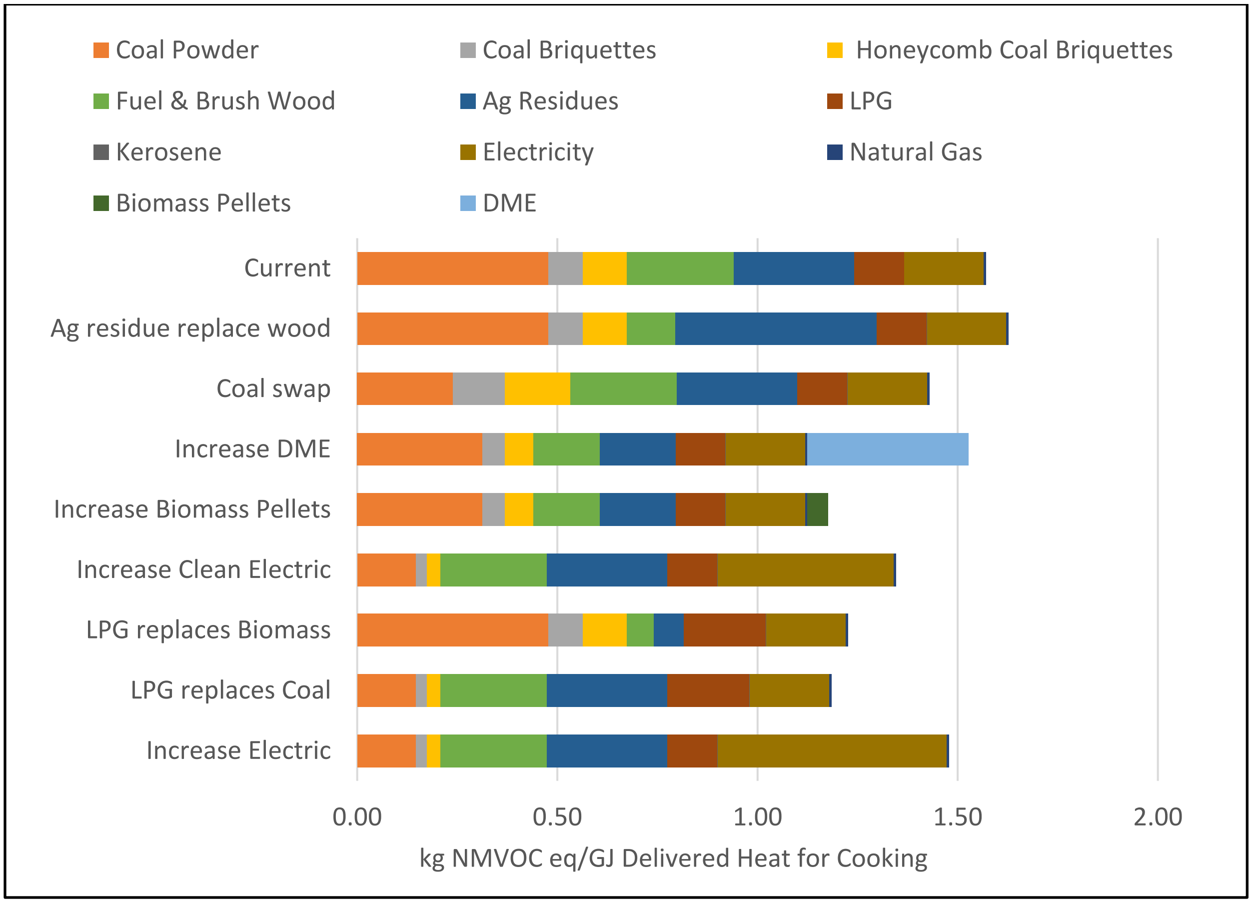


Figure 4-16. Photochemical Oxidant Formation Potential for Current and Future Fuel Mix Scenarios in China

4.2.7 Freshwater Eutrophication Potential

Figure 4-17 shows the results of potential fuel use scenarios on the freshwater eutrophication impacts. Agricultural residues dominate the results in this impact category due to land application of crop residue ash after combustion. Consequently, the scenario where Ag residues replace wood based biomass yields the largest overall impact among the studied scenarios. The scenario in which LPG replaces biomass yields the lowest overall result. Pelletization of biomass fuels prior to their use as a cooking fuel also results in improved environmental performance within this impact category, including the beneficial effect of higher efficiencies for pellet stoves.

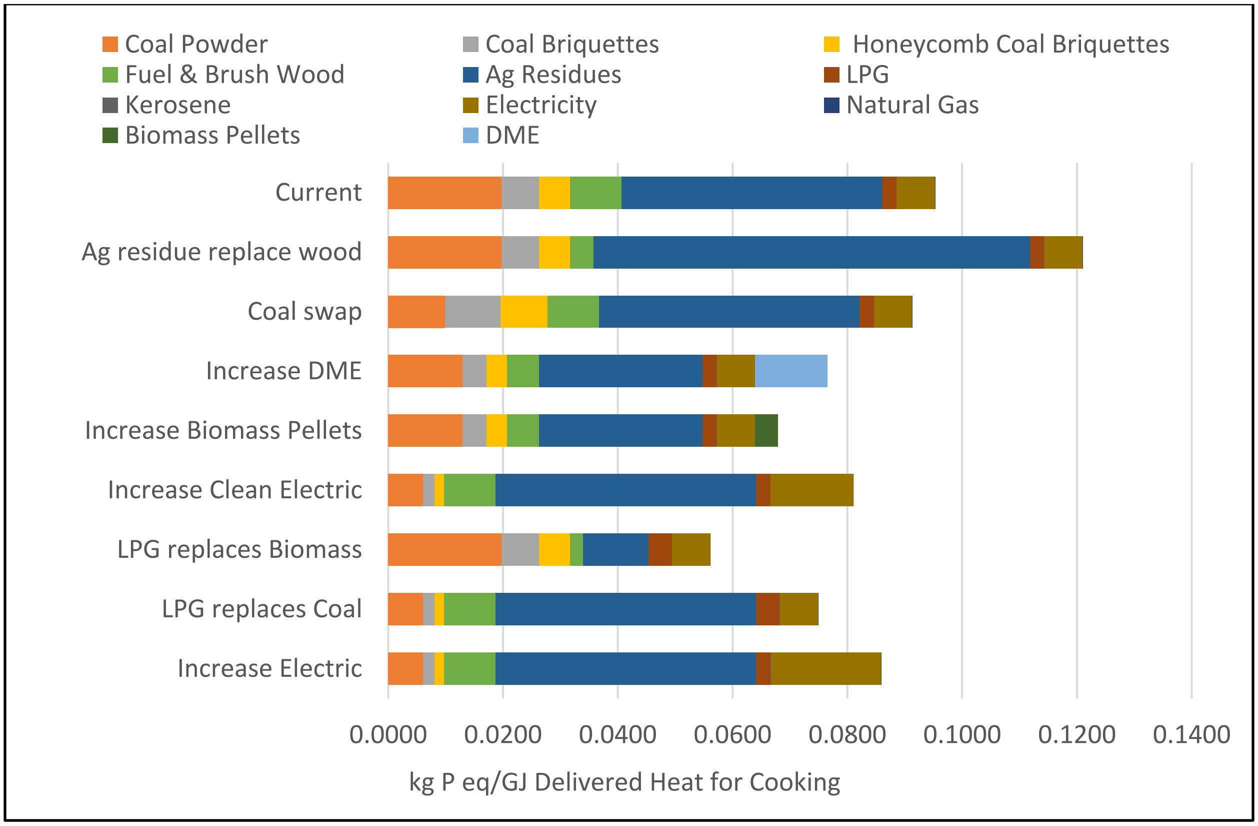


Figure 4-17. Freshwater Eutrophication Potential for Current and Future Fuel Mix Scenarios in China

4.2.8 Terrestrial Acidification Potential

The effects of fuel use scenarios on terrestrial acidification potential impacts are depicted in Figure 4-18. Both switching electricity for coal and LPG for biomass, Scenarios 1 and 3 respectively, lead to an increase in terrestrial acidification impacts. However, the increase is not a dramatic one. Substituting LPG for coal leads to a more significant decrease in acidification impacts, and the lowest overall impact score of all the studied scenarios. The burning of coal either directly in stoves or as a feedstock for electricity production is a driver of impacts in this category.

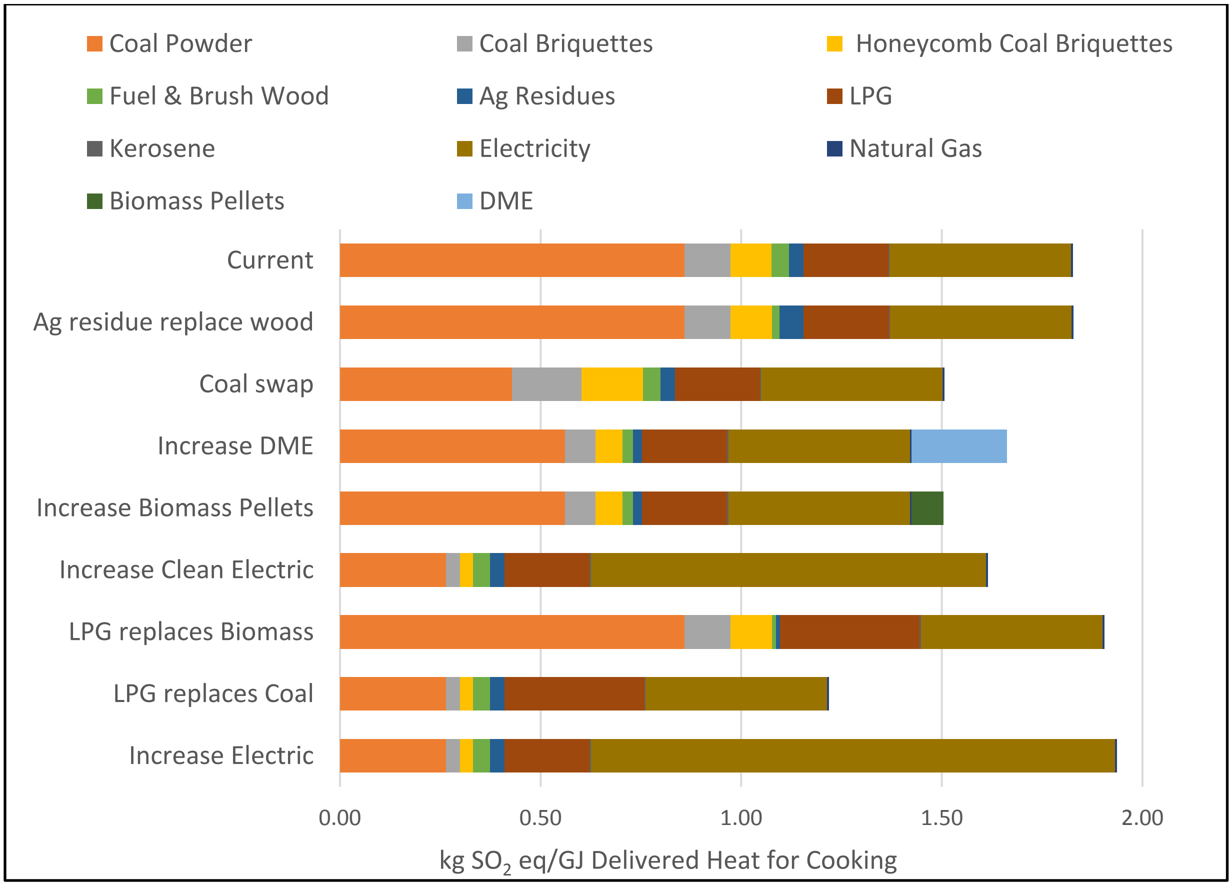


Figure 4-18. Terrestrial Acidification Potential for Current and Future Fuel Mix Scenarios in China

4.2.9 Ozone Depletion Potential

Figure 4-19 shows the effect of fuel use scenarios on ozone depletion impacts. In general, the scenario results are dominated by contributions from fossil fuels. Petroleum and coal-based fuels have a significantly higher contribution to ozone depletion per GJ of delivered heat than do biomass fuels. The scenarios where LPG or DME is used as a fuel substitute generates significantly greater ozone depletion impacts compared to the current scenario.

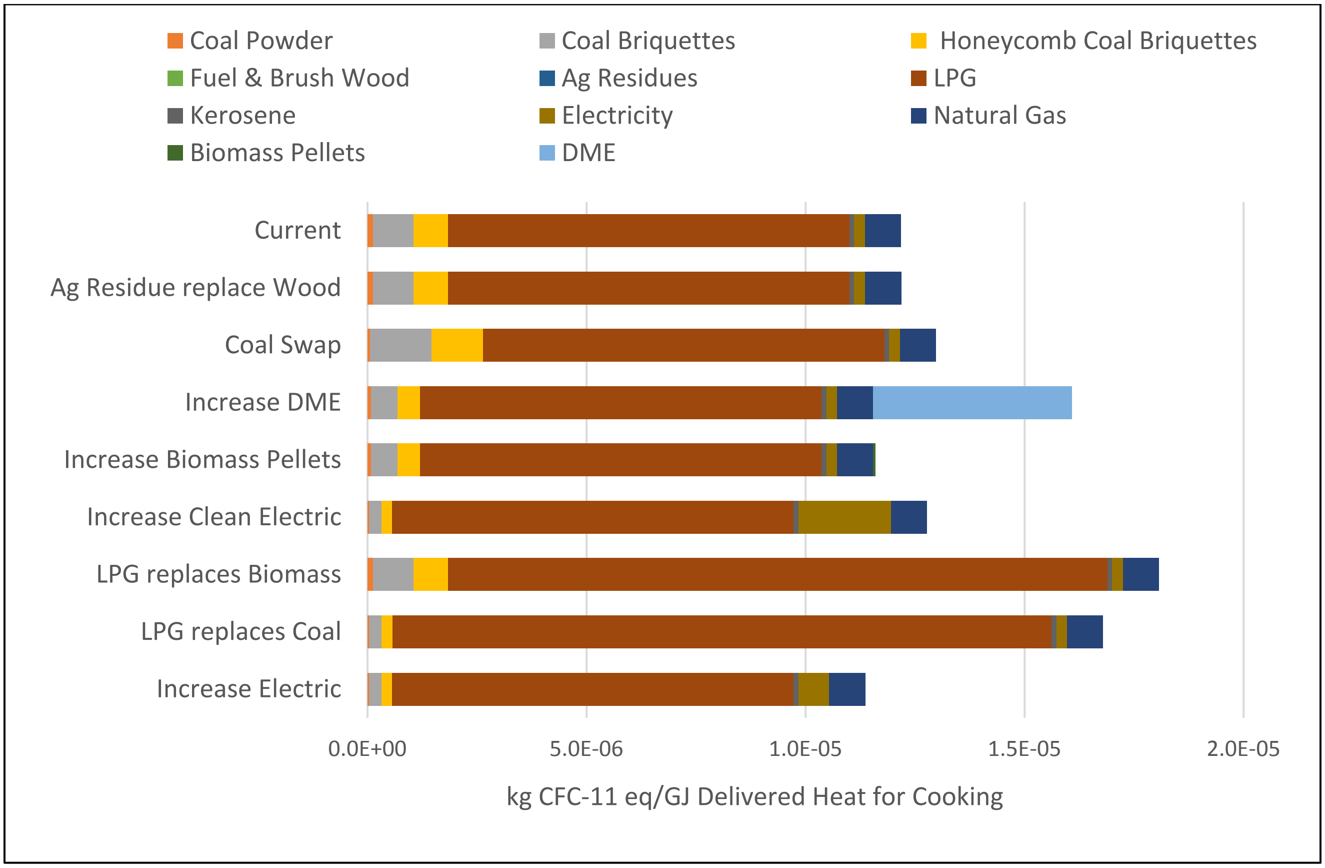


Figure 4-19. Ozone Depletion Potential for Current and Future Fuel Mix Scenarios in China

4.2.10 Black Carbon and Short-Lived Climate Pollutants

The contribution of studied fuel mix scenarios on black carbon impacts are depicted in Figure 4-20. Biomass based cooking fuels dominate results in the study scenarios. Unlike other impact categories, there are negative results associated with LPG, kerosene, electricity and natural gas fuels that contribute to the various scenarios. For these fuels the cooling effects of SOx and organic carbon emissions exceed the contribution to warming created by the other emissions, leading to a net negative radiative forcing impact. These negative values are not sufficient in any of the scenarios to completely eliminate the contribution of black carbon emissions to climate change. The Ag residue scenario has the greatest overall BC impact and exceeds that of the current scenario. The scenario in which LPG replaces biomass has the lowest net impacts among the scenarios within this impact category.

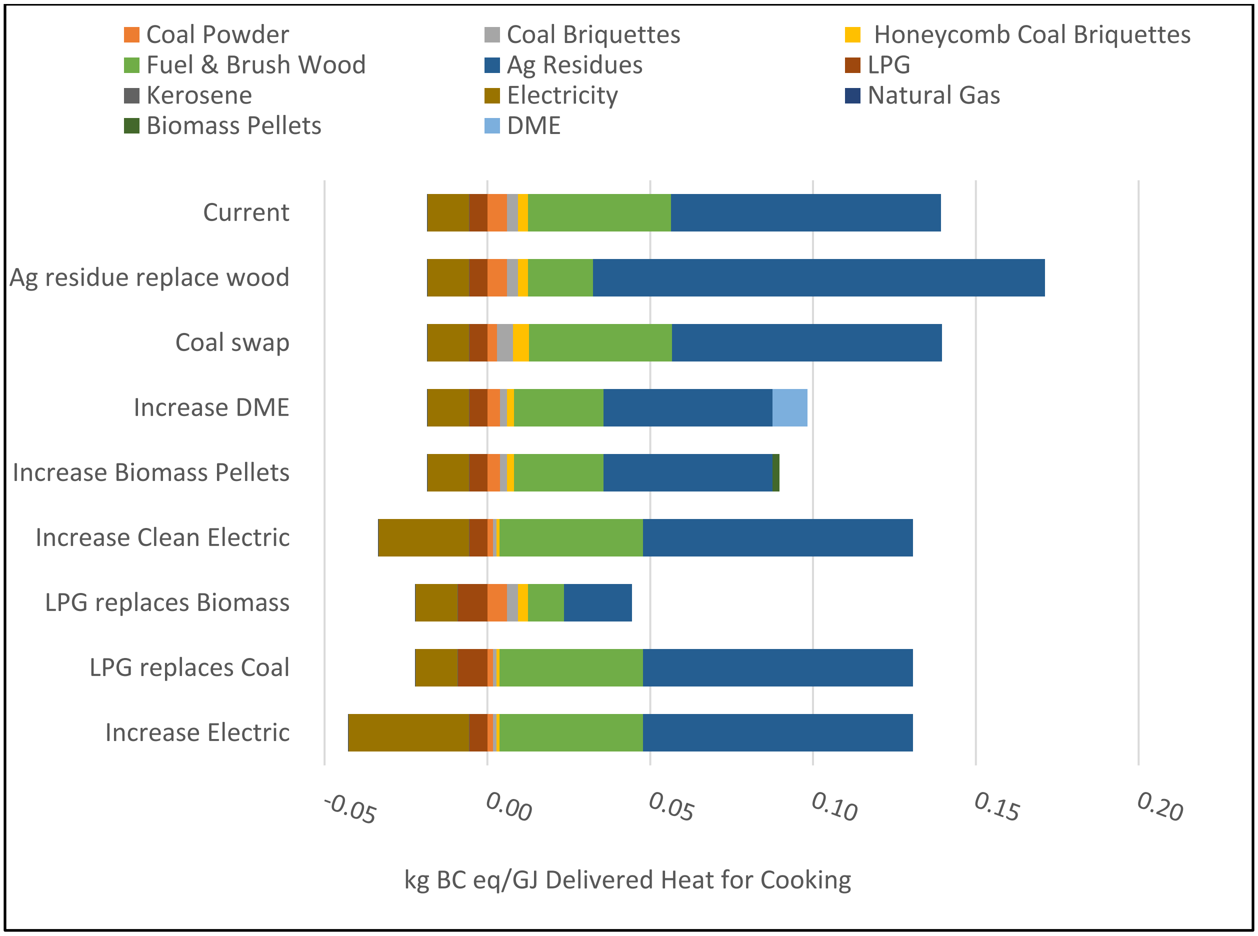


Figure 4-20. Black Carbon and Short-Lived Climate Pollutant Impacts for Current and Future Fuel Mix Scenarios in China

4.2.11 Relative Impacts of Current and Cleaner Electrical Grid Scenarios in China

Two scenarios were developed that featured an increase in the use of electrical energy as a cooking fuel. One of these scenarios was developed using the current national grid energy mix as it exists in China. The second scenario is based on projections regarding the introduction of a cleaner mix of fuels into the Chinese national grid. The result of these grid scenarios for each impact category are depicted in the previous section. Figure 4-21 and Figure 4-22 display the relative impacts of each grid per GJ of delivered heat, with each figure presenting results for five of the impact categories. The fuel mix for each of the grids is displayed in an earlier section in Table 2-4. In the clean electric grid scenario, a fraction of the coal-fired generation is replaced with hydropower, natural gas, wind, and nuclear energy. These substitutions yields an improvement in environmental performance in eight of the ten impact categories between 1 and 25%. Ozone depletion and black carbon impacts are both higher in the cleaner grid scenario, with ozone depletion impacts increasing by 69%. The increase in black carbon impacts is due to the decreased contribution of coal in the cleaner electricity mix. The sulfur based particulate emissions associated with coal exhibit a short-term cooling effect, thereby decreasing black carbon impacts, relative to the clean electricity scenario. Coal also has a relatively low ozone depletion potential when compared to the liquid fossil fuels, which explains the increase in ozone depletion impacts associated with the clean electricity mix scenario.

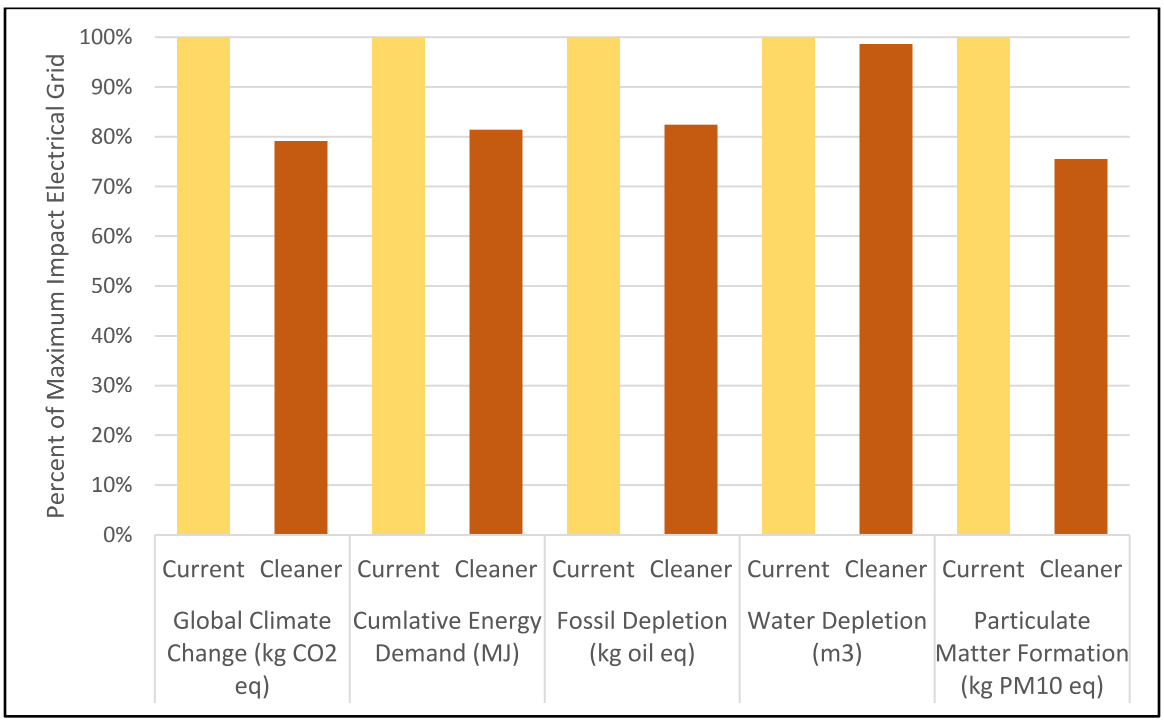


Figure 4-21. Relative Global Climate Change, Cumulative Energy Demand, Fossil Depletion, Water Depletion, and Particulate Matter Formation Impacts of Study Electricity Grids in China

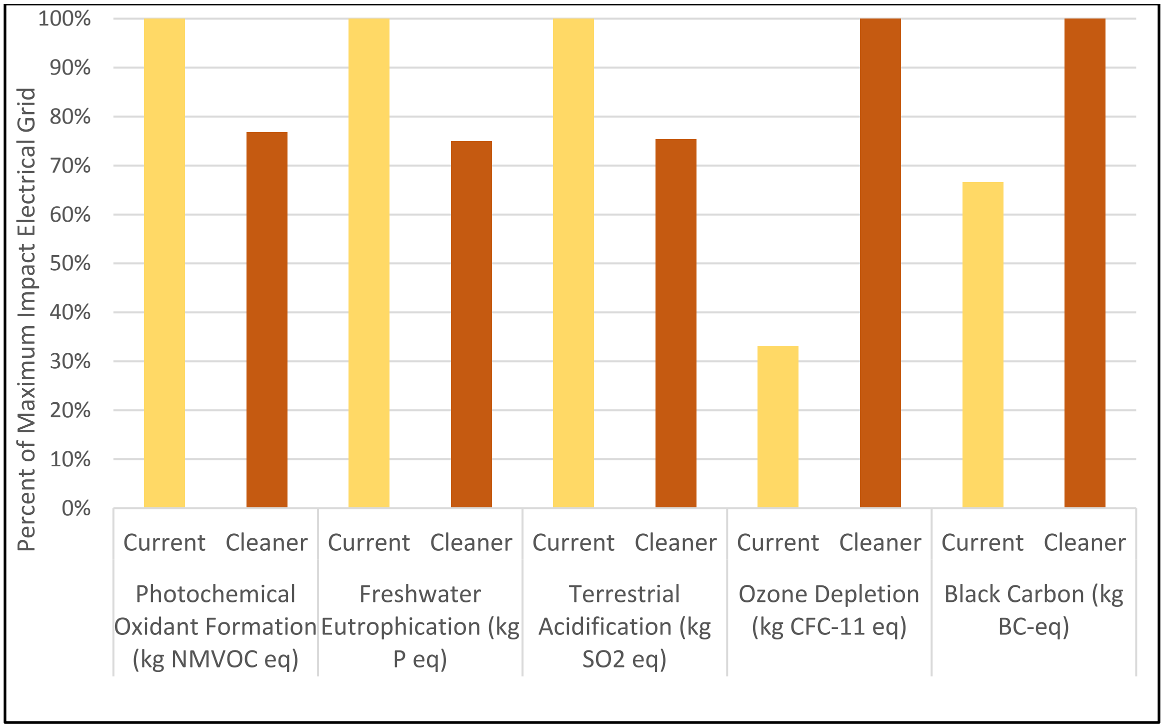


Figure 4-22. Relative Photochemical Oxidant Formation, Eutrophication, Acidification, Ozone Depletion, and Black Carbon Impacts of Study Electricity Grids in China

4.3 Summary Tables for Fuel and Fuel Scenarios in China.

This section presents summary tables that allow an easier (simplified) visual side-by-side comparison of individual fuels and fuel scenarios across impact categories. In each indicator column, the results are assigned numbers, with lower numbers and green coloration associated with lower (better) relative environmental results. The numbering and color coding should not be interpreted as indications that differences between fuels and fuels scenarios are statistically significant. A binary interpretation as comparatively better systems (green) and relatively worse systems (yellow) is more appropriate. Additionally, the relative importance of individual impact categories themselves is subjective and should be considered carefully when interpreting the results or drawing conclusions about the performance of one fuel or fuel scenario over another.

Despite these cautionary statements and the trade-offs that exist between impact categories, Table 4-1 does show some notable trends across the considered fuels. Natural gas, biomass pellets, and LPG are generally in the higher end of environmental performance with some exceptions. The various forms of coal emerge as having consistently worse relative environmental performance for most impacts. It is also interesting to note the tradeoffs in areas where unprocessed biomass fuels perform well (fossil fuel, water, acidification, ozone) and where they perform poorly (particulate matter, photochemical oxidation, and black carbon).

Table 4-1. Ranked Performance of Fuels by Impact Category in China

	Climate Change	**Cumulative Energy Demand**	**Fossil Depletion**	**Water Depletion**	**Particulate Matter Formation**	**Photochemical Oxidant Formation**	**Freshwater Eutrophication**	**Terrestrial Acidification**	**Ozone Depletion**	**Black Carbon & Short-Lived Climate Pollutants**
Coal Mix	12	12	12	7	10	11	10	11	7	7
Coal Powder	13	13	13	5	12	13	11	13	5	6
Coal Briquettes	11	11	11	12	6	5	9	10	9	9
Honeycomb Coal Briquettes	10	9	10	10	5	6	8	9	8	8
Biomass Mix	3	8	2	2	11	10	12	3	2	12
Fuel & Brush Wood	7	7	1	1	9	7	5	2	1	11
Ag Residues	1	10	3	3	13	12	13	4	3	13
LPG	4	3	6	9	2	3	2	6	11	3
Kerosene	5	4	7	11	4	4	3	7	13	2
Electricity	9	5	8	13	8	8	6	12	6	1
Natural Gas	6	1	5	4	1	1	1	1	12	4
Biomass Pellets	2	2	4	8	3	2	4	5	4	5
DME	8	6	9	6	7	9	7	8	10	10

A summary table presenting the relative life cycle environmental results for each fuel scenario by impact category is included below in Table 4-2. Scenarios are numbered from 1 through 9 across rows corresponding to the magnitude of their relative results from lowest (best) to highest (worst) in each environmental impact category. Scenarios (columns) with more green have comparatively better environmental results than scenarios in columns with more yellow. As described for the previous table on individual fuels, the numerical values lack precision that would ideally be needed for meaningful conclusions about differences in life cycle environmental impact results; therefore, when interpreting results it is more appropriate to use the simplified color scale to identify fuel systems that tend to perform better (green) or worse (yellow) in the categories of interest.

The table shows that both the ‘Increase Biomass Pellet’ and ‘LPG replace Coal’ scenarios demonstrate better environmental performance in almost all impact categories. As with India, the current scenario has generally worse environmental performance for most indicators with a few exceptions. Interestingly, both electricity scenarios exhibit better relative performance in China than they do in the Indian context although the performance of the electricity scenarios has some unfavorable results for certain impact categories, including water depletion (for both electricity scenarios) and acidification (for increasing current electricity). Results for other scenarios are equally or more mixed. While these tables do not conclusively identify the best and worst options, they indicate where further analysis of model sensitivity and significance should be pursued.

Table 4-2. Ranked Performance of Fuel Scenarios by Impact Category in China

	Increase Electric	LPG replaces Coal	LPG replaces Biomass	Increase Clean Electric	Increase Biomass Pellets	Increase DME	Coal swap	Ag reside replace wood	Current
Climate Change	3	1	9	2	4	5	6	7	8
Cumulative Energy Demand	4	1	5	3	2	6	7	9	8
Fossil Depletion	3	1	9	2	4	8	5	7	6
Water Depletion	9	4	7	8	6	3	5	2	1
Particulate Matter Formation	7	3	1	5	2	4	6	9	8
Photochemical Oxidant Formation	6	2	3	4	1	7	5	9	8
Eutrophication	6	3	1	5	2	4	7	9	8
Acidification	9	1	8	4	2	5	3	7	6
Ozone Depletion	1	8	9	5	2	7	6	4	3
Black Carbon & Short-Lived Climate Pollutants	4	6	1	5	2	3	8	9	7

5. Conclusions and Next Steps

This study developed an LCA of commonly used cookstove fuels and potentially cleaner alternatives. LCA allows for a holistic assessment of the life cycle impacts of the fuel, including not only the impacts at point of use of the fuel but also the impacts associated with fuel feedstock production, fuel processing, and distribution. In addition to examining life cycle impacts for individual cookstove fuels in China and India, impacts of the current fuel mix and possible future changes to the fuel mix used in cookstoves were assessed.

Stove efficiency was found to be a key parameter driving impact results in both countries. Fuels used in stoves with higher efficiencies (e.g., LPG, kerosene, biogas, ethanol, natural gas, electricity and biomass pellets) had generally lower environmental impacts compared to low efficiency stoves burning traditional fuels (e.g., firewood, dung cake, crop residues, and coal). In India, biogas consistently emerged as a low-impact fuel across the majority of life cycle impact categories. Ethanol from sugarcane also performed well in most categories; however, higher water depletion impacts were seen for this fuel since irrigation is required during cane production. This could be a particular challenge in India, which is currently a water-stressed nation. None of the other fuels exhibit such consistently high or low performance, although results for dung cake and hard coal are often found on the lower end of environmental performance. Traditional fuels had particularly high impacts for particulate matter formation and black carbon emissions. For China, natural gas, biomass pellets, and LPG generally showed lower (better) life cycle impacts in most categories, with some exceptions. The various forms of coal investigated emerged as having consistently worse relative environmental performance. These impacts are also transferred to electricity based systems that also rely upon coal as a major fuel source. Water impacts were also significant for electricity due to the contribution of hydroelectric power to the grid mix. Establishments of dams for hydropower leads to notable evaporative losses. The findings from the individual cooking fuel type analysis were then leveraged to understand the results from the fuel mix scenarios.

5.1 Key Takeaways

The following are the key takeaways from the comparison of the environmental footprint of the baseline and possible cooking fuel mixes in India:

- Firewood makes the largest contribution to GCCP across all fuel mix scenarios, since firewood makes up roughly 30% to 50% of fuel use, depending on the scenario, and 41% of harvested wood in India is considered non-renewable.

- If households are able to replace firewood with another fuel with low climate change impacts, such as biogas from dung, ethanol from sugarcane, or biomass pellets, the environmental footprint of the cooking fuel mix will improve.

- The highest energy demand comes from the use of firewood and dung which are used within traditional cookstoves. The traditional mud stoves used with these fuels are extremely inefficient, which increases amount of fuel (and therefore, energy) required to deliver a GJ of useful cooking energy, compared to more efficient cookstoves used for processed fuels.

- Increasing use of electricity (whether India's current electrical grid or a cleaner grid) would reduce energy demand; however, the improvement is small due to the fact that the electricity grid mix has a high percentage of fossil fuels.

- The lowest CED would be realized by replacing firewood and dung use with either advanced liquid fuels or biomass pellets using a high efficiency stove.

- The current mix of cookstove fuels in India has the lowest water depletion impacts compared to all the future scenarios. Increased electricity usage would greatly increase water depletion due to more evaporative water loss associated with hydroelectric dams. While it is desirable to move towards a cleaner grid mix by replacing coal with electricity from renewable sources, the increase in water consumption due to hydropower is noteworthy given the high water stress levels in India.

- Particulate matter and photochemical oxidant formation from cookstoves in India could both be reduced if any of the potential future cookstove fuel mix scenarios were achieved, especially in the scenarios where dung cake or firewood are replaced with cleaner burning fuels such as LPG, kerosene, biogas, or biomass pellets.

- Even though dung cake currently only provides about 10% or less of total cookstove energy for Indian households, its combustion results in a large quantity of land-applied ash that has significant freshwater eutrophication impacts. However, the nutrients from dung are likely necessary for agricultural production regardless of whether the dung cake is burnt. Shifting to use of LPG, biogas, ethanol or biomass pellets would reduce eutrophication considerably.

- Terrestrial acidification is not greatly affected by changes in cookstove fuel mixes, except that acidification would rise with increased electricity use due to higher SOx emissions from greater use of coal.

- Except for scenarios where biomass is replaced with another bio-based fuel like biogas or biomass pellets, the current fuel mix scenario has the lowest ozone depletion impacts.

- Since traditional biomass is the main source of black carbon emissions shifting the cookstove fuel mix towards fossil fuels or processed biomass fuels would result in decreased impacts.

The following are the key takeaways from the comparison of the environmental footprint of the baseline and possible cooking fuel mixes in China:

- Replacing some coal use with LPG or biomass pellets or greater use of a cleaner electricity grid would significantly reduce GCCP, CED, and fossil depletion impacts.

- If households are able to replace coal with another fuel with low climate change impacts, such as agricultural residues or biomass pellets, the GCCP of the cooking fuel mix will improve.

- Replacing agricultural residue and fuelwood use with LPG or DME would cause an increase in fossil depletion.

- The current cookstove fuels mix and the scenarios with agriculture residue replacing fuel wood have the lowest water depletion impacts in comparison with other future scenarios. Increased electricity usage would significantly increase water depletion due to more evaporative water loss associated with hydroelectric dams.

- Particulate matter formation from cookstoves in China could be reduced if any of the potential future cookstove fuel mix scenarios were achieved with the exception of increasing agricultural residue use. Replacing biomass or coal with LPG, kerosene, DME, or biomass pellets is especially effective. Even replacing coal powder with coal briquettes would have a beneficial effect.

- Replacing traditional biomass or coal powder with LPG or biomass pellets or increasing use of electricity with a cleaner grid would lead to reduced photochemical oxidant formation impacts.

- Increasing agricultural residue use would increase freshwater eutrophication impacts, while all other potential cookstove fuel mix scenarios diminish eutrophication impacts compared to the baseline scenario.

- In scenarios where coal use is shifted to other fuels, terrestrial acidification decreases. However, acidification would rise with increased electricity use due to higher SOx emissions from greater use of coal in the generation of electricity.

- SOx emissions from combustion of fossil fuels such as LPG, coal combustion at power plants, kerosene, and natural gas reduce radiative forcing while traditional biomass emissions raise black carbon impacts. Thus, replacing inefficient biomass cookstoves with a highly efficient LPG cookstove would lower black carbon emissions and resulting impacts.

Overall trends and observations about similarities and differences in LCA results for India and China include the following:

- The production and use of coal requires the most energy and has the greatest amount of climate change potential. Therefore, any reduction of coal will result in a better environmental footprint for the cooking fuel use within either country.

- Processed biomass energy sources such as biogas from dung in India and biomass pellets in China perform well across many of the LCA results categories in comparison to both traditional and fossil fuels. Scenarios where these fuels partially displace traditional biomass show some promise of reducing point of use emissions in the home that can be harmful to human health without significant tradeoffs such as increased global climate change potential or water depletion.

- Increased use of LPG in the future could also result in lower impacts for most LCA results categories in both countries. However, this is only true for certain scenarios where LPG replaces the worst performing fuels such as dung in India and coal in China.

- While increasing use of electric cookstoves will not decrease GCCP, CED, and fossil depletion impacts in India due to the large share of electricity that is generated from coal combustion, replacing use of coal cookstoves with electric cookstoves in China does result in reductions in these impact categories largely because the efficiency of the electric cookstove is so much higher than the efficiency of the coal cookstoves used in the home, and because some of the grid electricity is derived from cleaner, non-fossil sources such as hydropower.

- Finally, a large portion of energy demand and global climate change results originates from the use phase of the life cycle of the cooking fuels. The evaluated fuels have a range of heating values; however, when cooking, the amount of useful energy delivered to the cookstove depends not only on the energy content of the fuel, but also on the cookstove efficiency. If the cookstove has a low efficiency, more fuel must be used to provide a given amount of cooking energy. If more fuel is required due to the use of a low efficiency stove, the benefits of using a fuel with a low environmental profile could be offset.

5.2 Next Steps

This research built a framework model for examining the life cycle impacts of cookstove fuels in developing countries. There are a number of other research questions to examine within the LCA model, including refining modeling assumptions or using alternative modeling approaches. Several topics that may warrant further research include:

- While the focus of this study was on the cooking fuel supply-chain, the overall efficiency of the stove proved to be a key parameter influencing the environmental performance of the scenarios investigated. Future research tasks will involve analyzing ranges for assumed efficiencies by stove type to understand the potential minimum and maximum air emissions at point of use.

- As discussed in Chapter 2 Section 2.3, this study employed the cut-off allocation method. In this method, all burdens for the specified unit process are allocated to the primary product for a process that has multiple co-products. Several fuels examined such as crop residues, ethanol, and biogas are from multi-product output processes. For crop residues, no burdens for primary cultivation of the crop were assigned to the residues. Impacts may increase notably if choosing a different allocation method that partitions some of these burdens to the residue.

- Electricity is often a co-benefit of ethanol production. This study did not include a credit for grid electricity displaced by electricity co-produced with ethanol. Inclusion of this credit could decrease the overall environmental impacts for ethanol.

- Additionally, biogas results in digested sludge which may be land applied to benefit household level crop production. The potential incremental increase in crop production at the household was not evaluated in this assessment.

- Increasing the infrastructure and associated maintenance for some of the fuel scenarios assessed may have notable impacts if the current infrastructure in China and India cannot support the production volume increase. While this study excluded infrastructure from its scope, the relative impacts of increasing infrastructure and associated infrastructure maintenance for "clean" cooking fuel types could be investigated in the next research steps.

- It is apparent that there is a larger difference in environmental impacts between fuels than between the fuel mix scenarios; therefore, the study will investigate other, more differentiated scenarios. These future scenarios will consider how to optimize human and environmental impacts of cookstove fuels. Additional research will be conducted to understand the timeframe for when these fuels might penetrate urban or rural regions. More fuel mix scenarios will also be considered, such as expansion of piped natural gas in urban areas of China.

Conducting sensitivity analyses on these key allocation and scenario questions, and other assumptions such as the portion of fuel wood estimated to be sustainable in each country, would provide insight into the relative range of each fuel's environmental impact. This study collected multiple data points for energy inputs and emissions across the life cycle of each fuel where possible. Building on this robust foundation of existing data collected, uncertainty analyses using the Monte Carlo method may be performed to better interpret the range in results and determine significant differences between cooking fuel type burdens.

In addition to these sensitivity analyses, alternate visualizations of the results could help in the interpretation of the study findings. The magnitude of impact assessment results is often difficult to interpret. Normalization is an optional step in LCA that aids in understanding the significance of the impact assessment results. In future research to update and extend this study, normalization will be conducted by dividing the impact category results by a normalized value. The normalized value is typically the environmental burdens of the region of interest either on an absolute or per capita basis. In this task, we will evaluate normalized impact scores between impact categories to inform discussion of relative magnitude (and therefore importance) of different impacts from cooking fuels. The geographic scope of the analysis may also be extended to include other regions of the world such as Africa.

The environmental and human health impacts from burning traditional fuels are widespread in the developing world. The LCA model built here can serve as the basis to further understanding of the quantifiable tradeoffs between fuel choices to help spur initiatives to change cooking fuel use patterns. This work can be continually improved upon as it is enhanced with additional sensitivity and uncertainty analyses, and more current data on cookstove fuel impacts become publicly available.

The data presented in this report will be part of an EPA tool that provides users access to data and facilitates analyses to evaluate differences in fuels and other parameters that affect selection of future cookstove fuels. The tool will provide information on the LCA environmental tradeoffs that affect the environmental performance of cookstove fuels. The tool will also link to a Global Alliance for Clean Cookstoves' tool – the Fuel Analysis, Comparison and Integration Tool (FACIT) – providing information on environmental, economic and social impacts associated with several types of fuels used in cookstoves.

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APPENDIX A: DETAILED LCI UNIT PROCESS TABLES

The following tables provide the background LCI unit process data tables for both India and China. Table A-1 provides the Code Key for the each of the LCI unit process tables. Table A-2 presents a data quality key for all data quality indicators in each LCI unit process table. Table A-3 provides further description of the data quality indicators used. Table A-4 through Table A-28 show all energy and emissions data for each unit process used within the LCI models for India. Table A-29 through Table A-72 display all energy and emissions data for each unit process used within the LCI models for China.

Table A-1. Code Key for LCI Tables

Category	Code	Full Name
Input Groups	4	From Nature
	5	From Technosphere
Output Groups	0	Reference Product
	2	Co - Product
	4	To Nature
Countries [a]	CN	China
	IN	India
	MA	Morocco
	RER	Europe
	UCTE	Union for Co-ordination of Transmission of Electricity
	US	United States

[a] Countries indicate the location of the flow used for purposes of modeling. In some cases, India and China specific flows were not available, so other country datasets were applied, as indicated by the country code in the unit process tables.

Table A-2. Data Quality Index Methodology [1]

<table>
<tr><th rowspan="2">Indicator</th><th colspan="5">Score</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td rowspan="3">Source Reliability (for most applications, source quality guidelines are only factor)</td><td>data verified based on measurements</td><td>data verified based on some assumptions and/or standard science and engineering calculations</td><td>data verified with many assumptions, or non-verified but from quality source</td><td>qualified estimate</td><td>non-qualified estimate</td></tr>
<tr><td colspan="2">source quality guidelines met</td><td colspan="3">source quality guidelines not met</td></tr>
<tr><td>data cross checks, greater than or equal to 3 quality sources</td><td colspan="2">2 or fewer data sources available for cross check, or data sources available that do not meet quality standards</td><td colspan="2">no data available for cross check</td></tr>
</table>

Table A-2. Data Quality Index Methodology [1]

<table>
<tr><th rowspan="2">Indicator</th><th colspan="5">Score</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>Completeness</td><td>representative data from a sufficient sample of sites over an adequate period of time</td><td>smaller number of sites, but an adequate period of time</td><td>sufficient number of sites, but a less adequate period of time</td><td>smaller number of sites and shorter periods or incomplete data from an adequate number of sites or periods</td><td>representativeness unknown or incomplete data sets</td></tr>
<tr><td>Temporal Correlation</td><td>less than 3 years of difference to year of study/current year</td><td>less than 6 years of difference</td><td>less than 10 years of difference</td><td>less than 15 years of difference</td><td>age of data unknown or more than 15 years of difference</td></tr>
<tr><td>Geographical Correlation</td><td>data from area under study</td><td>average data from larger area or specific data from a close area</td><td>data from area with similar production conditions</td><td>data from area with slightly similar production conditions</td><td>data from unknown area or area with very different production conditions</td></tr>
<tr><td>Technological Correlation</td><td>data from technology, process, or materials being studied</td><td colspan="2">data from a different technology using the same process and/or materials</td><td>data on related process or material using the same technology</td><td>data or related process or material using a different technology</td></tr>
<tr><td>Uncertainty Correlation</td><td>data sample uncertainty measurement information is available; normal or logarithmic normal distribution</td><td>data sample uncertainty measurement information is available; triangle distribution</td><td>data sample uncertainty measurement information available; uniform distribution</td><td colspan="2">No uncertainty measurement information is available or data sample size = 1</td></tr>
<tr><td>Precision Correlation</td><td>logarithmic normal or normal distribution and low geometric standard or standard deviation</td><td colspan="3">logarithmic normal or normal distribution and high geometric standard or standard deviation; or triangle or uniform distribution</td><td>no dispersion information available</td></tr>
</table>

[1]Taken from US Federal Digital Commons Life Cycle Inventory unit Process Template; originally derived from NETL LCI&C Guideline Document, adapted from Weidema and Wenaes.

Table A-3. Data Quality Indicator Descriptions [1]

Source Reliability -- This indicator relates to the quality of the data source and the verification of the data collection methods used within the source.
Data Verification -- Source data that have been verified within error bounds by either the source author (with a high level of transparency) or the LCI modeler. Verification can be done by measurement, including on-site checking, recalculation, or mass or energy balance analysis. If the source data cannot be verified without making assumptions (e.g., not enough data are available to close the mass/energy balance), then the score should be a 2 or 3, depending on the number of assumptions. If no source data are available, a qualified estimate from an expert in the field should receive a score of 4, and an estimate from a non-expert should receive a score of 5. Mostly applicable to primary data.
Source Quality Guidelines -- The highest quality source should be o From a peer reviewed journal or a government sponsored study. If the source is an LCA, it must meet ISO requirements. o Publicly available either for free or at cost, or directly representative of the process of interest. o Written/published by an unbiased party. o An unbiased survey of experts or process locations. When the source used for data is a reputable model that does not specifically meet the above criteria, it is the discretion of the modeler to determine the rank of the source. An example for justification would be if the data have been used in published reports that met the data quality standards.
Data Cross-Check -- The number of sources that verify the same data point or series, within reason. As a general benchmark, a high standard is greater than or equal to three data cross checks with quality approved sources. *This typically refers to primary data, and if no other data sources are available, this can be omitted.*
Completeness -- This indicator quantifies the statistical robustness of the source data. This ranking is based on how many data points were taken, how representative the sample is to the studied process, and whether the data were taken for an acceptable time period to even out normal process fluctuations. The following examples are given to help clarify this indicator.
Temporal Correlation -- This indicator represents how well the time period in which the data were collected corresponds with the year of the study. If the study is set to evaluate the use of a technology from 2000 to 2040, data from 1970 would not be very accurate. It is important when assigning this ranking to take notice of any discrepancies between the year the source was published and the year(s) the data were collected.
Geographical Correlation -- This indicator represents the appropriateness between the region of study and the source data region. This indicator becomes important when comparing data from different countries. For example, technological advances might reasonably be expected to develop differently in different countries, so efficiency and energy use might be very different. This is also important when looking at best management practices for carbon mitigation.
Technological Correlation -- This indicator embodies all other differences that may be present between the study goals and the data source. From the above example, using data for a type of biomass that is not being studied in the LCA should result in a lower technological representativeness ranking.
Uncertainty Correlation -- This indicator represents the characterization of the dispersion of values attributed to a measured quantity; it has probabilistic basis and relates to how well the measurement upon which the input or output value is derived was performed.
Precision Correlation -- This indicator represents the degree of spread or variability in a set of data values or measurements relative to the mean of the data values; it reflects the degree to which the measurement/experimental system used to derive the input/output value is reproducible and repeatable to achieve the same results.

[1]Taken from US Federal Digital Commons Life Cycle Inventory unit Process Template; originally derived from NETL LCI&C Guideline Document, adapted from Weidema and Wenaes.

India LCI Unit Process Tables

Table A-4. Biogas; Production from Dung; At Anaerobic Digester (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Biogas; Production From Dung; at Anaerobic Digester			IN	**1.00**	kg								1
4		Energy, Calorific Value, in Organic Substance	energy resources	renewable energy resources		**18.2**	MJ	2	2	2	2	1	4	5	1
	4	Carbon Dioxide	air	unspecified		**5.7E-05**	kg	2	2	2	2	1	4	5	1,2,3,4,5,6
	4	Methane	air	unspecified		**0.036**	kg	2	2	2	2	1	4	5	1,2,3,4,5,6
	2	Digested Slurry			IN	**1.06**	kg	2	2	2	2	1	4	5	1,2,3,4,5,6
	4	Nitrogen	air	unspecified		**5.3E-4**	kg	2	2	2	2	1	4	5	1,2,3,4,5,6
	4	Hydrogen Sulfide	air	(unspecified)		**2.2E-5**	kg	2	2	2	2	1	4	5	1,2,3,4,5,6
4		Water, unspecified Natural Origin/kg	resource	in water		**10.4**	kg	2	2	2	2	1	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

[2] Singh, P., and H., Gundimeda. 2014b. Life cycle energy analysis (LCEA) of cooking fuel sources used in India households. Energy and Environmental Engineering 2(1): 20-30.

[3] UN (United Nations). 2007. Bagepalli CDM project: project definition document. https://cdm.unfccc.int/filestorage/s/c/62U354IQDXJKCZSPORVW01LYAG9H7T.pdf/121-20130813-PDD.pdf?t=TnN8bnh5cTFyfDCrNtJ4UeZWTopC4hnYrrMO. Accessed 17 November 2015.

[4] Vivekanandan S. and G., Kamraj. 2011. Investigation on cow dung as co-substrate with pre-treated sodium hydroxide on rice chaff for efficient biogas production. International Journal of Science and Advanced Technology 1(4): 76-80.

[5] Afrane G., and A. Ntiamoah. 2011. Comparative life cycle assessment of charcoal, biogas and LPG as cooking fuels in Ghana. Journal of Industrial Ecology. 15(4): 539-549.

[6] Borjesson P., and M. Berglund. 2006. Environmental systems analysis of biogas systems–Part 1: fuel-cycle emissions. Biomass and Bioenergy 30(5): 469-485.

Table A-5. Charcoal; Production from Wood; At Earth Mound Kiln (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Completeness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Charcoal; Production from Wood; at Earth Mound Kiln			IN	**1.00**	kg								1
4		Energy, Gross Calorific Value, in Biomass, Primary Forest	resource	biotic		**11.8**	MJ	2	2	3	3	1	4	5	2
4		Energy, Gross Calorific Value, in Biomass	resource	biotic		**37.2**	MJ	2	2	3	3	1	4	5	2
	4	Carbon Dioxide	air	unspecified		**1.25**	kg	2	2	3	3	1	4	5	1
	4	Carbon Monoxide	air	unspecified		**0.28**	kg	2	2	3	3	1	4	5	1
	4	Methane	air	unspecified		**0.030**	kg	2	2	3	3	1	4	5	1
	4	Nitrogen Oxides	air	unspecified		**3.8E-05**	kg	2	2	3	3	1	4	5	1
	4	Dinitrogen Monoxide	air	unspecified		**4.8E-05**	kg	2	2	3	3	1	4	5	1
	4	Particulates, > 2.5 Um, and < 10um	air	unspecified		**0.090**	kg	2	2	3	3	1	4	5	1
	4	NMVOC, Non-Methane Volatile Organic Compounds, unspecified Origin	air	unspecified		**0.013**	kg	2	2	3	3	1	4	5	1
5		Disposal, Wood Ash Mixture, Pure, 0% Water, to Land farming			CH	**0.062**	kg	2	2	3	3	1	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

[2] Singh, P., and H., Gundimeda. 2014b. Life cycle energy analysis (LCEA) of cooking fuel sources used in India households. Energy and Environmental Engineering 2(1): 20-30.

Table A-6. Electricity; Average Production; At Consumer; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Completeness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Electricity; average production; at consumer; production mix			IN	**1.00**	kWh								1
5		Electricity, hard coal, at power plant			IN	**0.92**	kWh	3	2	2	2	2	4	5	1
5		Electricity, natural gas, at power plant			IN	**0.11**	kWh	3	2	2	2	2	4	5	1
5		Electricity, oil, at power plant			IN	**0.026**	kWh	3	2	2	2	2	4	5	1
5		Electricity, hydropower, at reservoir power plant, non alpine regions			RER	**0.14**	kWh	3	2	2	4	3	4	5	1
5		Electricity, nuclear, at power plant			UCTE	**0.038**	kWh	3	2	2	4	3	4	5	1
5		Electricity, at wind power plant			RER	**0.033**	kWh	3	2	2	4	3	4	5	1
5		Electricity, at cogen with biogas engine, allocation exergy			CH	**0.022**	kWh	3	2	2	4	3	4	5	1
5		Electricity, production mix photovoltaic, at plant			US	**0.0024**	kWh	3	2	2	4	3	4	5	1

[1] IEA (International Energy Agency). 2012. India: Electricity and heat for 2012 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=electricityandheat&year=2012. Accessed 17 November 2015.

Table A-7. Hard Coal; Extraction; At Open Cast Mine (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Completeness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Hard Coal; Extraction; at Open Cast Mine			IN	**1.00**	kg								1
4		Coal, Hard	resource	in ground		**1.00**	kg	2	2	3	1	2	4	5	1
5		Diesel; Production From Crude Oil; at Plant; Production Mix			IN	**6.9E-04**	kg	2	2	3	1	2	4	5	1,3,4
	4	Carbon Dioxide	air	unspecified		**0.0022**	kg	2	2	3	1	2	4	5	1,3,4
	4	Carbon Monoxide	air	unspecified		**7.2E-04**	kg	2	2	3	1	2	4	5	1,3,4
	4	Methane	air	unspecified		**9.5E-04**	kg	2	2	3	1	2	4	5	1,3,4
	4	Nitrogen Oxides	air	unspecified		**2.0E-04**	kg	2	2	3	1	2	4	5	1,4,5
	4	Dinitrogen Monoxide	air	unspecified		**9.6E-08**	kg	2	2	3	1	2	4	5	1,3,4
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.0029**	kg	2	2	3	1	2	4	5	1,3,4
	4	NMVOC, Non-Methane Volatile Organic Compounds, unspecified Origin	air	unspecified		**2.5E-06**	kg	2	2	3	1	2	4	5	1,3,4
	4	Sulfur Dioxide	air	unspecified		**2.1E-05**	kg	2	2	3	1	2	4	5	1,3,4
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.5E-05**	kg	2	2	3	1	2	4	5	1,3,4
	4	Suspended Solids, unspecified	water	unspecified		**4.2E-05**	kg	2	2	3	1	2	4	5	1,3,4
	4	Fluorine	water	unspecified		**1.2E-06**	kg	2	2	3	1	2	4	5	1,3,4
	4	Chlorine	water	unspecified		**3.8E-05**	kg	2	2	3	1	2	4	5	1,3,4

Table A-7. Hard Coal; Extraction; At Open Cast Mine (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	Sulfur	water	unspecified		**4.2E-04**	kg	2	2	3	1	2	4	5	1,3,4
	4	Nitrate	water	unspecified		**2.0E-08**	kg	2	2	3	1	2	4	5	1,3,4
	4	Zinc	water	unspecified		**8.6E-07**	kg	2	2	3	1	2	4	5	1,3,4
	4	Manganese	water	unspecified		**7.2E-06**	kg	2	2	3	1	2	4	5	1,3,4
4		Water, Well, in Ground	resource	in ground		**5.6E-04**	m^3	2	2	2	3	2	4	5	2

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

[2] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. *Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. [Life cycle of energy systems: foundations for the ecological comparison of energy systems and the inclusion of energy systems in life cycle assessment for the Switzerland*.] Final report ecoinvent No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dubendorf, CH.

[3] Ghose, M.K. 2004. Emission factors for the quantification of dust in Indian coal mines. Journal of Scientific and Industrial Research. 63(9): 763-768.

[4] Ghose, M.K. 2007. Generation and quantification of hazardous dusts from coal mining in the Indian context. Environmental Monitoring and Assessment 130(1-3): 35-45.

Table A-8. LPG; Production from Natural Gas; at Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	LPG; Production from Natural Gas; At Plant; Production Mix			IN	**1.00**	kg								1
	4	NMVOC, Non-Methane Volatile Organic Compounds, unspecified Origin	air	unspecified		**5.0E-04**	kg	2	2	2	1	1	4	5	1
	4	Sulfur Dioxide	air	unspecified		**0.035**	kg	2	2	2	1	1	4	5	1
	4	Carbon Dioxide	air	unspecified		**0.064**	kg	2	2	2	1	1	4	5	1
	4	Carbon Monoxide	air	unspecified		**1.0E-04**	kg	2	2	2	1	1	4	5	1
	4	Methane	air	unspecified		**0.013**	kg	2	2	2	1	1	4	5	1
	4	Nitrogen Oxides	air	unspecified		**0.0014**	kg	2	2	2	1	1	4	5	1
	4	Dinitrogen Monoxide	air	unspecified		**5.2E-06**	kg	2	2	2	1	1	4	5	1
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**4.4E-04**	kg	2	2	2	1	1	4	5	1
5		Electricity; Average Production; At Consumer; Production Mix			IN	**0.30**	kWh	2	2	2	1	2	4	5	1
5		Natural Gas; Extraction; At Plant; Production Mix			IN	**8.61**	kg	2	2	2	1	1	4	5	1
5		Transport, Natural Gas, Pipeline, Long Distance			RER	**2.50**	t*km	2	2	2	4	3	4	5	1
	2	Lean Gas; Production from Natural Gas; At Plant; Production Mix			IN	**11.4**	kg	2	2	2	1	1	4	5	1
	2	Naptha; Production from Natural Gas; At Plant; Production Mix			IN	**0.34**	kg	2	2	2	1	1	4	5	1
	4	Ammonia	air	unspecified		**7.3E-06**	kg	2	2	2	1	1	4	5	1
	4	Aldehydes, unspecified	air	unspecified		**3.7E-06**	kg	2	2	2	1	1	4	5	1
4		Water, unspecified Natural Origin/kg	resource	in water		**0.20**	kg	2	2	2	1	1	4	5	1
5		Propane/ Butane, At Refinery			RER	**0.0043**	kg	2	2	2	4	3	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-9. LPG from Crude Oil; Petroleum Refining; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	LPG from crude oil; petroleum refining; at plant; production mix			IN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**6.3E-04**	kg	2	1	1	3	1	2	1	1
	4	Sulfur dioxide	air	unspecified		**0.048**	kg	2	1	1	3	1	2	1	1
	4	Carbon dioxide	air	unspecified		**4.59**	kg	2	1	1	3	1	2	1	1
	4	Carbon monoxide	air	unspecified		**1.22**	kg	2	1	1	3	1	2	1	1
	4	Methane	air	unspecified		**0.022**	kg	2	1	1	3	1	2	1	1
	4	Nitrogen oxides	air	unspecified		**0.017**	kg	2	1	1	3	1	2	1	1
	4	Dinitrogen monoxide	air	unspecified		**3.3E-05**	kg	2	1	1	3	1	2	1	1
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.023**	kg	2	1	1	3	1	2	1	1
5		Electricity; average production; at consumer; production mix			IN	**0.024**	kWh	2	1	1	1	1	1	1	1
5		Crude oil; extraction; at plant; production mix			IN	**27.3**	kg	2	1	1	1	1	1	1	1
	4	Ammonia	air	unspecified		**0.0049**	kg	2	1	1	3	1	2	1	1
	4	Aldehydes, unspecified	air	unspecified		**0.0016**	kg	2	1	1	3	1	2	1	1
5		Propane/ butane, at refinery			RER	**1.00**	kg	2	1	1	5	1	3	1	1
5		Transport, combination truck, average fuel mix			US	**5.47**	t*km	2	1	1	5	1	3	1	1
5		Operation, freight train			RER	**16.4**	t*km	2	1	1	5	1	3	1	1
	2	Kerosene; production from crude oil; at plant; production mix			IN	**1.02**	kg	2	1	1	1	1	1	1	1
	2	Motor spirit; production from crude oil; at plant; production mix			IN	**3.47**	kg	2	1	1	1	1	1	1	1

Table A-9. LPG from Crude Oil; Petroleum Refining; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	2	Naptha; production from crude oil; at plant; production mix			IN	**2.33**	kg	2	1	1	1	1	1	1	1
	2	Other petroleum products; production from crude oil; at plant; production mix			IN	**3.09**	kg	2	1	1	1	1	1	1	1
	2	Fuel oil; production from crude oil; at plant; production mix			IN	**2.72**	kg	2	1	1	1	1	1	1	1
	2	Diesel; production from crude oil; at plant; production mix			IN	**10.4**	kg	2	1	1	1	1	1	1	1
5		Diesel; production from crude oil; at plant; production mix			IN	**0.038**	kg	2	1	1	1	1	1	1	1
5		Transport, transoceanic freight ship			OCE	**9.57**	t*km	2	1	1	3	1	1	1	1
4		Water, surface	resource	in water		**34.8**	kg	2	1	1	1	1	1	1	1
4		Water, ground	resource	in water		**7.84**	kg	2	1	1	1	1	1	1	1
5		Fuel oil; production from crude oil; at plant; production mix			IN	**0.62**	kg	2	1	1	1	1	1	1	1
	2	Jet fuel; production from crude oil; at plant; production mix			IN	**1.27**	kg	2	1	1	1	1	1	1	1
	4	Catalyst waste	final-waste-flow	unspecified		**0.0014**	kg	2	1	1	1	1	1	1	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**5.1E-05**	kg	2	1	1	2	1	2	1	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**4.3E-04**	kg	2	1	1	2	1	2	1	1
	4	Suspended solids, unspecified	water	unspecified		**6.8E-05**	kg	2	1	1	2	1	2	1	1
	4	Phenol	water	unspecified		**1.2E-06**	kg	2	1	1	2	1	2	1	1
	4	Oils, unspecified	water	unspecified		**1.7E-05**	kg	2	1	1	2	1	2	1	1
	4	Sulfide	water	unspecified		**1.7E-06**	kg	2	1	1	2	1	2	1	1

Table A-9. LPG from Crude Oil; Petroleum Refining; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	Ammonia	water	unspecified		**5.1E-05**	kg	2	1	1	2	1	2	1	1
	4	Phosphorus	water	unspecified		**1.0E-05**	kg	2	1	1	2	1	2	1	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-10. Molasses; Production from Sugarcane; At Plant (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Completeness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Molasses; production from sugarcane; at plant			IN	**0.050**	kg								1
	2	Sugar; production from sugarcane; at plant			IN	**0.091**	kg	2	2	2	1	1	4	5	1
	2	Electricity; average production; at consumer; production mix			IN	**0.054**	kWh	2	2	3	1	1	4	5	1,2
5		Sugarcane; production; at farm			IN	**1.00**	kg	2	2	2	1	1	4	5	1
5		Sulphur dioxide, liquid, at plant			RER	**0.0015**	kg	2	2	2	4	3	4	5	1
5		Limestone, at mine			US	**0.0019**	kg	2	2	2	4	3	4	5	1
5		Sodium hydroxide, 50% in H_2O, production mix, at plant			RER	**5.0E-04**	kg	2	2	2	4	3	4	5	1
5		Single superphosphate, as P_2O_5, at regional storehouse			RER	**1.0E-04**	kg	2	2	2	4	3	4	5	1
5		Soda, powder, at plant			RER	**3.0E-05**	kg	2	2	2	4	3	4	5	1
5		Chemicals organic, at plant			GLO	**1.0E-05**	kg	2	2	2	2	3	4	5	1
5		Lubricating oil, at plant/RER U			RER	**6.0E-04**	kg	2	2	2	4	3	4	5	1
4		Water, unspecified natural origin/kg	resource	in water		**0.030**	kg	2	2	2	1	1	4	5	1
5		Phosphoric acid, industrial grade, 85% in H_2O, at plant			RER	**1.0E-05**	kg	2	2	2	4	3	4	5	1
5		Transport, combination truck, average fuel mix			US	**0.013**	t*km	2	2	2	4	3	4	5	1

[1]Tsiropoulos, I., A.P.C., Faaij, J.E.A. Seabra, et al. 2014. Life cycle assessment of sugarcane ethanol production in India in comparison to Brazil. International Journal of Lifecycle Assessment 19: 1049-1067.

[2]Prakash R., A., Henham, and I.K. Bhat. 2005. Gross carbon emissions from alternative transport fuels in India. Energy for Sustainable Development 9(2): 10-16.

Table A-11. Sugarcane; Production; At Farm (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Sugarcane; production; at farm			IN	**1.00**	kg								1
4		Occupation, arable	resource	land		**0.17**	m^2*a	2	2	2	1	1	4	5	1
4		Water, unspecified natural origin/m^3	resource	in water		**0.060**	m^3	2	2	2	1	1	4	5	1
5		Ammonium sulphate, as N, at regional storehouse			RER	**4.2E-04**	kg	2	2	2	4	2	4	5	1
5		Ammonium nitrate, as N, at regional storehouse			RER	**4.2E-04**	kg	2	2	2	4	2	4	5	1
5		Diammonium phosphate, as N, at regional storehouse			RER	**3.7E-04**	kg	2	2	2	4	2	4	5	1
5		Potassium nitrate, as N, at regional storehouse			RER	**2.5E-04**	kg	2	2	2	4	2	4	5	1
5		Urea, as N, at regional storehouse			RER	**0.0012**	kg	2	2	2	4	2	4	5	1
5		Diammonium phosphate, as P_2O_5, at regional storehouse			RER	**6.2E-04**	kg	2	2	2	4	2	4	5	1
5		Single superphosphate, as P_2O_5, at regional storehouse			RER	**4.0E-04**	kg	2	2	2	4	2	4	5	1
5		Triple superphosphate, as P_2O_5, at regional storehouse			RER	**2.0E-04**	kg	2	2	2	4	2	4	5	1
5		Phosphate rock, as P_2O_5, beneficiated, dry, at plant			MA	**7.0E-05**	kg	2	2	2	4	2	4	5	1
5		Potassium chloride, as K_2O, at regional storehouse			RER	**8.0E-04**	kg	2	2	2	4	2	4	5	1
5		Potassium nitrate, as K_2O, at regional storehouse			RER	**8.0E-06**	kg	2	2	2	4	2	4	5	1
5		Potassium sulphate, as K_2O, at regional storehouse			RER	**8.0E-06**	kg	2	2	2	4	2	4	5	1
5		Herbicides, at regional storehouse			RER	**5.6E-05**	kg	2	2	2	4	2	4	5	1
5		Triazine-compounds, at regional storehouse			RER	**1.1E-05**	kg	2	2	2	4	2	4	5	1
5		Phenoxy-compounds, at regional storehouse			RER	**3.0E-06**	kg	2	2	2	4	2	4	5	1
5		Glyphosate, at regional storehouse			RER	**4.0E-06**	kg	2	2	2	4	2	4	5	1
5		Diuron, at regional storehouse			RER	**9.0E-06**	kg	2	2	2	4	2	4	5	1
5		Insecticides, at regional storehouse			RER	**5.0E-05**	kg	2	2	2	4	2	4	5	1

Table A-11. Sugarcane; Production; At Farm (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
5		Fungicides, at regional storehouse			RER	**3.0E-06**	kg	2	2	2	4	2	4	5	1
5		Electricity; average production; at consumer; production mix			IN	**0.012**	kWh	2	2	2	1	1	4	5	1
5		Diesel, combusted in industrial equipment			US	**5.4E-04**	l	2	2	2	3	2	4	5	1
4		Energy, gross calorific value, in biomass	resource	biotic		**4.95**	MJ	2	2	2	3	2	4	5	1
	4	Dinitrogen monoxide	air	unspecified		**0.30**	kg	2	2	2	3	2	4	5	2
	4	Phosphorus	water	unspecified		**7.3E-06**	kg	2	2	2	3	2	4	5	1

[1] Tsiropoulos, I., A.P.C., Faaij, J.E.A. Seabra, et al. 2014. Life cycle assessment of sugarcane ethanol production in India in comparison to Brazil. International Journal of Lifecycle Assessment 19: 1049-1067.

[2] Macedo, I.C., J.E.A., Seabra, and J.E.A.R., Silva. 2008. Greenhouse gases emissions in the production and use of ethanol from sugarcane in Brazil: the 2005/2006 averages and a prediction for 2020. Biomass and Bioenergy 32(7): 582-595.

Table A-12. Ethanol; Production from Sugarcane Molasses; At Plant (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	Ethanol; production from sugarcane molasses; at plant			IN	**1.00**	kg								1
	2	Electricity; average production; at consumer; production mix			IN	**0.060**	kWh	2	2	2	1	1	4	5	1
5		Molasses; production from sugarcane; at plant			IN	**5.06**	kg	2	2	2	1	1	4	5	1
5		Sulphuric acid, liquid, at plant			RER	**4.1E-04**	kg	2	2	2	4	2	4	5	1
5		Magnesium sulphate, at plant			RER	**1.1E-04**	kg	2	2	2	4	2	4	5	1
5		Urea, as N, at regional storehouse			RER	**0.0013**	kg	2	2	2	4	2	4	5	1
5		Phosphoric acid, industrial grade, 85% in H_2O, at plant			RER	**1.4E-04**	kg	2	2	2	4	2	4	5	1
5		Chlorine, liquid, production mix, at plant			RER	**3.8E-04**	kg	2	2	2	4	2	4	5	1
5		Soda, powder, at plant			RER	**6.0E-05**	kg	2	2	2	4	2	4	5	1
5		Chromium oxide, flakes, at plant			RER	**1.0E-04**	kg	2	2	2	4	2	4	5	1
5		Sodium hydroxide, 50% in H_2O, production mix, at plant			RER	**6.0E-04**	kg	2	2	2	4	2	4	5	1
5		Zinc, primary, at regional storage			RER	**1.2E-04**	kg	2	2	2	4	2	4	5	1
5		Formaldehyde, production mix, at plant			RER	**2.0E-05**	kg	2	2	2	4	2	4	5	1
4		Water, unspecified natural origin/m^3	resource	in water		**0.011**	m^3	2	2	2	1	1	4	5	1
5		Transport, combination truck, average fuel mix			US	**0.38**	t*km	2	2	2	3	2	4	5	1

[1] Tsiropoulos, I., A.P.C., Faaij, J.E.A. Seabra, et al. 2014. Life cycle assessment of sugarcane ethanol production in India in comparison to Brazil. International Journal of Lifecycle Assessment 19: 1049-1067.

Table A-13. Biomass Pellet Production, At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Biomass pellets; at consumer			IN	**1.00**									1
4		Energy, gross calorific value, in biomass	resource	biotic		**12.3**	MJ	1	2	2	1	1	2	3	2,3
4		Energy, gross calorific value, in biomass, primary forest	resource	biotic		**5.41**	MJ	1	2	2	1	1	2	3	2,3
5		Electricity; average production; at consumer; production mix			IN	**0.27**	kWh	2	2	3	2	2	4	5	1
5		Transport, lorry >16t, fleet average			RER	**0.060**	t*km	2	2	3	2	2	4	5	1
5		Operation, freight train			RER	**0.12**	t*km	2	2	3	2	2	4	5	1
5		Disposal, wood untreated, 20% water, to sanitary landfill			CH	**0.29**	kg	1	2	2	1	1	2	3	1

[1] Jungbluth N., M., Chudacoff, and A., Dauriat, et al. 2007b. Life Cycle Inventories of Bioenergy. Final report ecoinvent data v2.0. Volume: 17. Swiss Centre for LCI, ESU. Duebendorf and Uster, CH.ESU. Duebendorf and Uster, CH.

[2] Dalberg Global Development Advisors. 2013. India cookstoves and fuels market assessment. Global Alliance for Clean Cookstoves. www.cleancookstoves.org/resources_files/india-cookstove-and-fuels-market-assessment.pdf. Accessed 6 October 2014.

[3] Singh, P., and H., Gundimeda. 2014b. Life cycle energy analysis (LCEA) of cooking fuel sources used in India households. Energy and Environmental Engineering 2(1): 20-30.

Table A-14. Crude Oil; Extraction; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Crude oil; extraction; at plant; production mix			IN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**4.6E-05**	kg	2	2	2	1	1	4	5	1
	4	Sulfur dioxide	air	unspecified		**3.9E-06**	kg	2	2	2	1	1	4	5	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**2.4E-05**	kg	2	2	2	1	1	4	5	1
	4	Suspended solids, unspecified	water	unspecified		**2.4E-05**	kg	2	2	2	1	1	4	5	1
	4	Carbon dioxide	air	unspecified		**0.046**	kg	2	2	2	1	1	4	5	1
	4	Carbon monoxide	air	unspecified		**1.4E-04**	kg	2	2	2	1	1	4	5	1
	4	Methane	air	unspecified		**0.0017**	kg	2	2	2	1	1	4	5	1
	4	Nitrogen oxides	air	unspecified		**3.2E-04**	kg	2	2	2	1	1	4	5	1
	4	Dinitrogen monoxide	air	unspecified		**1.0E-06**	kg	2	2	2	1	1	4	5	1
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**5.1E-05**	kg	2	2	2	1	1	4	5	1
5		Diesel; production from crude oil; at plant; production mix			IN	**0.0070**	kg	2	2	2	1	1	4	5	1
5		Electricity; average production; at consumer; production mix			IN	**0.020**	kWh	2	2	2	2	2	4	5	1
4		Water, unspecified natural origin/kg	resource	in water		**0.95**	kg	2	2	2	1	1	4	5	1
5		Lubricating oil, at plant			RER	**3.4E-04**	kg	2	2	2	3	3	4	5	1
4		Oil, crude	resource	in ground		**1.04**	kg	2	2	2	1	1	4	5	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**7.0E-06**	kg	2	2	2	1	1	4	5	1
	4	Chloride	water	unspecified		**1.4E-04**	kg	2	2	2	1	1	4	5	1
	4	Sulfate	water	unspecified		**2.4E-04**	kg	2	2	2	1	1	4	5	1
	4	Phenol	water	unspecified		**3.0E-07**	kg	2	2	2	1	1	4	5	1
	4	Oils, unspecified	water	unspecified		**8.0E-06**	kg	2	2	2	1	1	4	5	1

Table A-14. Crude Oil; Extraction; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	Dissolved organics	water	unspecified		**5.0E-04**	kg	2	2	2	1	1	4	5	1
	4	Oil waste	final-waste-flow	unspecified		**0.013**	kg	2	2	2	1	1	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-15. Natural Gas; Extraction; At Plant; Production Mix (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Natural gas; extraction; at plant; production mix			IN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**4.5E-05**	kg	2	2	2	1	1	4	5	1
	4	Sulfur dioxide	air	unspecified		**3.8E-06**	kg	2	2	2	1	1	4	5	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**2.3E-05**	kg	2	2	2	1	1	4	5	1
	4	Suspended solids, unspecified	water	unspecified		**2.3E-05**	kg	2	2	2	1	1	4	5	1
	4	Carbon dioxide	air	unspecified		**0.045**	kg	2	2	2	1	1	4	5	1
	4	Carbon monoxide	air	unspecified		**1.4E-04**	kg	2	2	2	1	1	4	5	1
	4	Methane	air	unspecified		**0.0017**	kg	2	2	2	1	1	4	5	1
	4	Nitrogen oxides	air	unspecified		**3.1E-04**	kg	2	2	2	1	1	4	5	1
	4	Dinitrogen monoxide	air	unspecified		**9.0E-07**	kg	2	2	2	1	1	4	5	1
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**5.0E-05**	kg	2	2	2	1	1	4	5	1
5		Diesel; production from crude oil; at plant; production mix			IN	**0.0069**	kg	2	2	2	1	1	4	5	1
5		Electricity; average production; at consumer; production mix			IN	**0.020**	kWh	2	2	2	2	2	4	5	1
4		Water, unspecified natural origin/kg	resource	in water		**0.93**	kg	2	2	2	1	1	4	5	1
5		Lubricating oil, at plant			RER	**1.5E-03**	kg	2	2	2	3	3	4	5	1
4		Gas, natural, in ground	resource	in ground		**1.04**	kg	2	2	2	1	1	4	5	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**7.0E-06**	kg	2	2	2	1	1	4	5	1
	4	Chloride	water	unspecified		**1.4E-04**	kg	2	2	2	1	1	4	5	1
	4	Sulfate	water	unspecified		**2.3E-04**	kg	2	2	2	1	1	4	5	1
	4	Phenol	water	unspecified		**3.0E-07**	kg	2	2	2	1	1	4	5	1
	4	Oils, unspecified	water	unspecified		**7.0E-06**	kg	2	2	2	1	1	4	5	1
	4	Dissolved organics	water	unspecified		**4.9E-04**	kg	2	2	2	1	1	4	5	1
	4	Oil waste	final-waste-flow	unspecified		**0.012**	kg	2	2	2	1	1	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-16. Bottling; LPG from Crude Oil; At Plant (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Bottling; LPG from crude oil; at plant			IN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.4E-05**	kg	2	2	1	1	1	4	5	1
5		Electricity; average production; at consumer; production mix			IN	**0.025**	kWh	2	2	1	1	2	4	5	1
5		LPG from crude oil; petroleum refining; at plant; production mix			IN	**1.04**	kg	2	2	1	1	1	4	5	1
4		Water, unspecified natural origin/m^3	resource	in water		**1.3E-04**	m^3	2	2	1	1	1	4	5	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**1.5E-06**	kg	2	2	1	1	1	4	5	1
	4	Chloride	water	unspecified		**4.9E-05**	kg	2	2	1	1	1	4	5	1
	4	Sulfate	water	unspecified		**4.9E-05**	kg	2	2	1	1	1	4	5	1
	4	Phenol	water	unspecified		**2.5E-07**	kg	2	2	1	1	1	4	5	1
	4	Oils, unspecified	water	unspecified		**9.8E-07**	kg	2	2	1	1	1	4	5	1
	4	Dissolved organics	water	unspecified		**1.0E-04**	kg	2	2	1	1	1	4	5	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.2E-05**	kg	2	2	1	1	1	4	5	1
	4	Suspended solids, unspecified	water	unspecified		**4.9E-06**	kg	2	2	1	1	1	4	5	1
	4	Sulfide	water	unspecified		**1.4E-07**	kg	2	2	1	1	1	4	5	1
	4	Ammonia	water	unspecified		**2.5E-07**	kg	2	2	1	1	1	4	5	1
5		Transport, combination truck, average fuel mix			US	**0.21**	t*km	2	2	2	4	3	4	5	1
5		Operation, freight train			RER	**0.62**	t*km	2	2	2	4	3	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-17. Bottling; LPG from Natural Gas; At Plant (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Bottling; LPG from natural gas; at plant			IN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.4E-05**	kg	2	2	1	1	1	4	5	1
5		Electricity; average production; at consumer; production mix			IN	**0.025**	kWh	2	2	1	1	2	4	5	1
5		LPG; production from natural gas; at plant; production mix			IN	**1.04**	kg	2	2	1	1	1	4	5	1
4		Water, unspecified natural origin/m^3	resource	in water		**1.3E-04**	m^3	2	2	1	1	1	4	5	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**1.5E-06**	kg	2	2	1	1	1	4	5	1
	4	Chloride	water	unspecified		**4.9E-05**	kg	2	2	1	1	1	4	5	1
	4	Sulfate	water	unspecified		**4.9E-05**	kg	2	2	1	1	1	4	5	1
	4	Phenol	water	unspecified		**2.5E-07**	kg	2	2	1	1	1	4	5	1
	4	Oils, unspecified	water	unspecified		**9.8E-07**	kg	2	2	1	1	1	4	5	1
	4	Dissolved organics	water	unspecified		**1.0E-04**	kg	2	2	1	1	1	4	5	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.2E-05**	kg	2	2	1	1	1	4	5	1
	4	Suspended solids, unspecified	water	unspecified		**4.9E-06**	kg	2	2	1	1	1	4	5	1
	4	Sulfide	water	unspecified		**1.4E-07**	kg	2	2	1	1	1	4	5	1
	4	Ammonia	water	unspecified		**2.5E-06**	kg	2	2	1	1	1	4	5	1
5		Transport, combination truck, average fuel mix			US	**0.21**	t*km	2	2	2	4	3	4	5	1
5		Operation, freight train			RER	**0.62**	t*km	2	2	2	4	3	4	5	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-18. Heat from Biomass Pellets; Pellet Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	Heat from biomass pellets; pellet stove; at consumer			IN	**1.00**	GJ								
5		Biomass pellets; at consumer			IN	**96.7**	kg	1	1	2	3	1	4	5	1
	4	Carbon dioxide, biogenic	air	low population density		**3.4E+01**	kg	1	1	2	3	1	4	5	1
	4	Carbon monoxide, biogenic	air	low population density		**9.0E-02**	kg	1	1	2	3	1	4	5	1
	4	Dinitrogen monoxide	air	low population density		**0.0E+00**	kg	1	1	2	3	1	4	5	1
	4	Methane, biogenic	air	low population density		**1.0E-01**	kg	1	1	2	3	1	4	5	1
	4	Nitrogen oxides	air	low population density		**6.0E-02**	kg	1	1	2	3	1	4	5	2
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	low population density		**0.0E+00**	kg	1	1	2	3	1	4	5	1
	4	Particulates, < 2.5 um	air	low population density		**9.0E-02**	kg	1	1	2	3	1	4	5	1
	4	Sulfur dioxide	air	low population density		**0.0E+00**	kg	1	1	2	3	1	4	5	1
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CH	**2.9E-04**	kg	1	1	2	3	1	4	5	1

[1] Jetter, J., Y., Zhao, K.R., Smith, et al. 2012. Pollutant emissions and energy efficiency under controlled conditions for household biomass cookstoves and implications for metrics useful in setting international test standards. Environmental Science & Tecal test standards. Environmental Science & Technology, 46: 10827-10834.

[2] Boman, C. 2005. Particulate and gaseous emissions from residential biomass combustion. Ph.D thesis, Umea University, Umea, Sweden.

Table A-19. Heat from Sugarcane Ethanol; Alcohol Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from sugarcane ethanol; alcohol stove; at consumer			IN	**1.00**	GJ								1
	4	Carbon dioxide	air	unspecified		**63.0**	kg	2	2	2	2	2	3	4	1
	4	Carbon monoxide	air	unspecified		**1.35**	kg	2	2	2	2	2	3	4	1
	4	Methane	air	unspecified		**0.038**	kg	2	2	2	2	2	3	4	1
	4	Particulates, < 2.5 um	air	unspecified		**4.3E-04**	kg	2	2	2	2	2	3	4	2
5		Ethanol; production from sugarcane molasses; at plant			IN	**35.3**	kg	2	2	2	2	2	3	4	1
5		Transport, combination truck, average fuel mix			US	**29.1**	t*km	2	2	3	5	3	4	5	3
5		Transport, van <3.5t			RER	**3.88**	t*km	2	2	3	5	3	4	5	3

[1] MacCarty, N. 2009. Results of Testing of the Clean Cook Stove for Fuel Use and Carbon Emissions. Aprovecho Research Center: Advanced Studies in Appropriate Technology Laboratory. www.aprovecho.org/lab/rad/rl/perf-stud/doc/125/raw. Accessed 17 November 2019.

[2] Aprovecho Research Center, Shell Foundation, U.S. EPA. Results of Testing of the Clean Cook Stove for Fuel Use and Carbon Emissions. 2011

[3] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

Table A-20. Heat from Biogas; Biogas Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from biogas; biogas stove; at consumer			IN	**1.00**	GJ								1,3,4,5
	4	Carbon dioxide, biogenic	air	unspecified		**145**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Carbon monoxide, biogenic	air	unspecified		**0.19**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Methane, biogenic	air	unspecified		**0.043**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Nitrogen oxides	air	unspecified		**0.038**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Sulfur dioxide	air	unspecified		**0.085**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Dinitrogen monoxide	air	unspecified		**9.0E-04**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.18**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**0.056**	kg	2	2	3	2	1	4	5	1,3,4,5
5		Biogas; production from dung; at anaerobic digester			IN	**100.0**	kg	2	2	3	2	1	4	5	1,2

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Table A-21. Heat from Charcoal; Metal Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from charcoal; metal stove; at consumer			IN	**1.00**	GJ								1
	4	Carbon dioxide, biogenic	air	unspecified		**543**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Carbon monoxide, biogenic	air	unspecified		**57.3**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Methane, biogenic	air	unspecified		**1.65**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Nitrogen oxides	air	unspecified		**0.24**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Sulfur dioxide	air	unspecified		**0.070**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Dinitrogen monoxide	air	unspecified		**0.016**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.63**	kg	2	2	3	2	1	4	5	1,3,4,5
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**2.15**	kg	2	2	3	2	1	4	5	1,3,4,5
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CH	**15.4**	kg	2	2	3	5	4	4	5	1,3,4,5
5		Charcoal; production from wood; at earth mound kiln			IN	**208**	kg	2	2	3	2	1	4	5	1, 2

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Table A-22. Heat from Hard Coal; Metal Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from hard coal; metal stove; at consumer			IN	1.00	GJ								1
	4	Carbon dioxide	air	unspecified		855	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Carbon monoxide	air	unspecified		26.9	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Methane	air	unspecified		2.57	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Nitrogen oxides	air	unspecified		0.55	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Sulfur dioxide	air	unspecified		1.46	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Dinitrogen monoxide	air	unspecified		4.4E-05	kg	2	2	3	3	1	4	5	1,3,4,5
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		17.2	kg	2	2	3	3	1	4	5	1,3,4,5
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		5.76	kg	2	2	3	3	1	4	5	1,3,4,5
5		Hard coal; extraction; at open cast mine			IN	554	kg	2	2	3	3	1	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CH	219	kg	2	2	3	5	4	4	5	1,3,4,5
5		Operation, freight train			RER	55.4	tkm	2	2	4	5	4	4	5	2

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Table A-23. Heat from Firewood; Traditional Mud Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from firewood; traditional mud stove; at consumer			IN	**1.00**	GJ								1,2
	4	Carbon dioxide, biogenic	air	unspecified		**721**	kg	2	2	3	1	1	4	5	1,3,6
	4	Carbon monoxide, biogenic	air	unspecified		**36.6**	kg	2	2	3	1	1	4	5	1,4,6
	4	Methane, biogenic	air	unspecified		**2.23**	kg	2	2	3	1	1	4	5	1,3,6
	4	Nitrogen oxides	air	unspecified		**0.41**	kg	2	2	2	1	1	4	5	1,5
	4	Sulfur dioxide	air	unspecified		**0.17**	kg	2	2	2	1	1	4	5	1,5
	4	Dinitrogen monoxide	air	unspecified		**0.047**	kg	2	2	3	1	1	4	5	1,3
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**4.60**	kg	2	2	2	1	1	4	5	1,4
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.90**	kg	2	2	2	1	1	4	5	1,5
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CH	**16.0**	kg	2	2	2	5	4	4	5	1,5
4		Energy, gross calorific value, in biomass, primary forest	resource	biotic		**5.86**	GJ	2	2	1	1	1	4	5	1,2
4		Energy, gross calorific value, in biomass	resource	biotic		**1.85**	GJ	2	2	1	1	1	4	5	1,2

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[5] Reddy M.S., and C., Venkataraman. 2002. Inventory of aerosol and sulphur dioxide emissions from India–Part I: fossil fuel combustion. Atmospheric Environment. 36(4): 677-697.

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Table A-24. Heat from Natural Gas LPG; LPG Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from natural gas LPG; LPG stove; at consumer			IN	**1.00**	GJ								1,3,4,5
	4	Carbon dioxide	air	unspecified		**120**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Carbon monoxide	air	unspecified		**0.58**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Methane	air	unspecified		**0.0030**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Nitrogen oxides	air	unspecified		**0.060**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Sulfur dioxide	air	unspecified		**0.082**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Dinitrogen monoxide	air	unspecified		**0.58**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.030**	kg	2	2	3	1	2	4	5	1,3,4,5
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**0.41**	kg	2	2	3	1	2	4	5	1,3,4,5
5		Bottling; LPG from natural gas; at plant			IN	**38.8**	kg	2	2	3	1	2	4	5	1
5		Transport, combination truck, average fuel mix			US	**29.1**	t*km	2	2	3	5	3	4	5	1,3,4,5
5		Transport, van <3.5t			RER	**3.88**	t*km	2	2	3	5	3	4	5	1,3,4,5

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Table A-25. Heat from Crop Residue; Traditional Mud Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from crop residue; traditional mud stove; at consumer			IN	**1.00**	GJ								1
	4	Carbon dioxide, biogenic	air	unspecified		**922**	kg	2	2	3	1	1	4	5	1,3,6
	4	Carbon monoxide, biogenic	air	unspecified		**46.4**	kg	2	2	3	1	1	4	5	1,4,6
	4	Methane, biogenic	air	unspecified		**4.81**	kg	2	2	3	1	1	4	5	1,3,6
	4	Nitrogen oxides	air	unspecified		**0.76**	kg	2	2	2	1	1	4	5	1,5
	4	Sulfur dioxide	air	unspecified		**0.19**	kg	2	2	2	1	1	4	5	1,5
	4	Dinitrogen monoxide	air	unspecified		**0.035**	kg	2	2	3	1	1	4	5	1,3
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**11.1**	kg	2	2	2	1	1	4	5	1,4
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**5.81**	kg	2	2	2	1	1	4	5	1,5
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CH	**19.1**	kg	2	2	2	5	4	4	5	1,5
4		Energy, gross calorific value, in biomass	resource	biotic		**9.67**	GJ	2	2	1	1	1	4	5	1,2

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Table A-26. Heat from Dung Cake; Traditional Mud Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from dung cake; traditional mud stove; at consumer			IN	**1.00**	GJ								1
	4	Carbon dioxide, biogenic	air	unspecified		**1,035**	kg	2	2	3	1	1	4	5	1,3,6
	4	Carbon monoxide, biogenic	air	unspecified		**39.5**	kg	2	2	3	1	1	4	5	1,4,6
	4	Methane, biogenic	air	unspecified		**5.64**	kg	2	2	3	1	1	4	5	1,3,6
	4	Nitrogen oxides	air	unspecified		**0.76**	kg	2	2	2	1	1	4	5	1,5
	4	Sulfur dioxide	air	unspecified		**0.32**	kg	2	2	2	1	1	4	5	1,5
	4	Dinitrogen monoxide	air	unspecified		**0.18**	kg	2	2	3	1	1	4	5	1,3
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**23.4**	kg	2	2	2	1	1	4	5	1,4
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**16.0**	kg	2	2	2	1	1	4	5	1,5
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CH	**390**	kg	2	2	2	5	4	4	5	1,5
4		Energy, calorific value, in organic substance	Energy resources	Renewable energy resources		**12.9**	GJ	2	2	1	1	1	4	5	1,2

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Table A-27. Heat from Crude Oil LPG; LPG Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from crude oil LPG; LPG stove; at consumer			IN	**1.00**	GJ								1,2,3,4
	4	Carbon dioxide	air	unspecified		**120**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Carbon monoxide	air	unspecified		**0.58**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Methane	air	unspecified		**0.003**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Nitrogen oxides	air	unspecified		**0.060**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Sulfur dioxide	air	unspecified		**0.082**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Dinitrogen monoxide	air	unspecified		**0.58**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.030**	kg	2	2	3	1	2	4	5	1,2,3,4
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**0.41**	kg	2	2	3	1	2	4	5	1,2,3,4
5		Bottling; LPG from crude oil; at plant			IN	**38.8**	kg	2	2	3	5	3	4	5	1
5		Transport, combination truck, average fuel mix			US	**29.1**	t*km	2	2	3	5	3	4	5	1,2,3,4

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

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[5] Kadian R., R.P., Dahiya, and H.P., Garg. 2007. Energy related emissions and mitigation opportunities from household sector in Dehli. Energy Policy 35(12): 6195-6211.

Table A-28. Heat from Kerosene; Kerosene Pressure Stove; At Consumer (IN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from kerosene; kerosene pressure stove; at consumer			IN	**1.00**	GJ								1
	4	Carbon dioxide	air	unspecified		**146**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Carbon monoxide	air	unspecified		**3.08**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Methane	air	unspecified		**0.036**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Nitrogen oxides	air	unspecified		**0.050**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Sulfur dioxide	air	unspecified		**0.13**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Dinitrogen monoxide	air	unspecified		**0.0045**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	Particulates, > 2.5 um, and < 10um	air	unspecified		**0.15**	kg	2	2	3	1	2	4	5	1,3,4,5,6
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**0.66**	kg	2	2	3	1	2	4	5	1,3,4,5,6
5		Kerosene; production from crude oil; at plant; production mix			IN	**49.6**	kg	2	2	3	1	2	4	5	2
5		Transport, combination truck, average fuel mix			US	**14.9**	t*km	2	2	3	5	3	4	5	1,3,4,5,6
5		Transport, van <3.5t			RER	**0**	t*km	2	2	3	5	3	4	5	1,3,4,5,6
5		Operation, freight train			RER	**0**	t*km	2	2	3	5	3	4	5	1,3,4,5,6

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.

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China LCI Tables

Table A-29. Biomass Pellets, At Consumer, National Mix (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
5		Fuel wood, at consumer			CN	**0.28**	kg	1	2	2	1	1	2	3	1,2
5		Brush wood, at consumer			CN	**0.28**	kg	1	2	2	1	1	2	3	1,2
5		Maize residue, at consumer			CN	**0.21**	kg	1	2	2	1	1	2	3	1,2
5		Wheat residue, at consumer			CN	**0.21**	kg	1	2	2	1	1	2	3	1,2
5		Rice straw, at consumer			CN	**0.025**	kg	1	2	2	1	1	2	3	1,2
5		Electricity, medium voltage, at grid 2011			CN	**0.30**	kWh	2	2	3	2	2	4	5	3,4
5		Transport, lorry >16t, fleet average			RER	**0.065**	t*km	2	2	3	2	2	4	5	3,4
5		Transport, freight, rail 2011			CN	**0.13**	t*km	2	2	3	2	2	4	5	3,4
	0	Biomass pellets, at consumer, national mix			CN	**1.00**	kg								3,4

[1] Jingjing L, Z., Xing, P., DeLauil P, et al. 2001. Biomass energy in China and its potential. Energy for Sustainable Development V(4): 66-80.

[2] Liu Z, A., Xu, and B. Long. 2011. Energy from combustion of rice straw: Status and challenges to China. Energy and Power Engineering 3(3): 325-331.

[3] Werner F., H.J., Althaus, and T., Künniger T, et al. 2007. Life cycle inventories of wood as fuel and construction material. Final report ecoinvent data v2.0 No. 9. Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

[4] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

Table A-30. Bottling, DME from Coal Gas, At Plant (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Bottling, DME from coal gas, at plant			CN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.4E-05**	kg	2	1	1	3	1	2	1	1
5		Electricity, production mix 2011			CN	**0.025**	kWh	2	1	1	3	1	2	1	1
5		Coal gas, at consumer			CN	**1.04**	kg	2	1	1	3	1	2	1	1
4		Water, unspecified natural origin/m^3	resource	in water		**1.3E-04**	m^3	2	1	1	3	1	2	1	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**1.5E-06**	kg	2	1	1	3	1	2	1	1
	4	Chloride	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Sulfate	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Phenol	water	unspecified		**2.5E-07**	kg	2	1	1	3	1	2	1	1
	4	Oils, unspecified	water	unspecified		**9.8E-07**	kg	2	1	1	3	1	2	1	1
	4	Dissolved organics	water	unspecified		**1.0E-04**	kg	2	1	1	3	1	2	1	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.2E-05**	kg	2	1	1	3	1	2	1	1
	4	Suspended solids, unspecified	water	unspecified		**4.9E-06**	kg	2	1	1	3	1	2	1	1
	4	Sulfide	water	unspecified		**1.4E-07**	kg	2	1	1	3	1	2	1	1
	4	Ammonia	water	unspecified		**2.5E-06**	kg	2	1	1	3	1	2	1	1
5		Transport, lorry >16t, fleet average			RER	**0.21**	t*km	2	1	1	3	1	2	1	1
5		Transport, freight, rail 2011			CN	**0.62**	t*km	2	1	1	3	1	2	1	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048 (Supplementary Materials S1-S6.)

Table A-31. Bottling, LPG from Crude Oil, At Plant (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Bottling, LPG from crude oil, at plant			CN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.4E-05**	kg	2	1	1	3	1	2	1	1
5		Electricity, production mix 2011			CN	**0.025**	kWh	2	1	1	3	1	2	1	1
5		Liquefied petroleum gas, at service station 2011			CN	**1.04**	kg	2	1	1	3	1	2	1	1
4		Water, unspecified natural origin/m^3	resource	in water		**1.3E-04**	m^3	2	1	1	3	1	2	1	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**1.5E-06**	kg	2	1	1	3	1	2	1	1
	4	Chloride	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Sulfate	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Phenol	water	unspecified		**2.5E-07**	kg	2	1	1	3	1	2	1	1
	4	Oils, unspecified	water	unspecified		**9.8E-07**	kg	2	1	1	3	1	2	1	1
	4	Dissolved organics	water	unspecified		**1.0E-04**	kg	2	1	1	3	1	2	1	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.2E-05**	kg	2	1	1	3	1	2	1	1
	4	Suspended solids, unspecified	water	unspecified		**4.9E-06**	kg	2	1	1	3	1	2	1	1
	4	Sulfide	water	unspecified		**1.4E-07**	kg	2	1	1	3	1	2	1	1
	4	Ammonia	water	unspecified		**2.5E-06**	kg	2	1	1	3	1	2	1	1
5		Transport, lorry >16t, fleet average			RER	**0.21**	t*km	2	1	1	3	1	2	1	1
5		Transport, freight, rail 2011			CN	**0.62**	t*km	2	1	1	3	1	2	1	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048 (Supplementary Materials S1-S6.)

Table A-32. Bottling, LPG from Natural Gas, At Plant (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Bottling, LPG from natural gas, at plant			CN	**1.00**	kg								1
	4	NMVOC, non-methane volatile organic compounds, unspecified origin	air	unspecified		**3.4E-05**	kg	2	1	1	3	1	2	1	1
5		Electricity, production mix 2011			CN	**0.025**	kWh	2	1	1	3	1	2	1	1
5		Liquefied petroleum gas, at service station 2011			CN	**1.04**	kg	2	1	1	3	1	2	1	1
4		Water, unspecified natural origin/m^3	resource	in water		**1.3E-04**	m^3	2	1	1	3	1	2	1	1
	4	BOD5, Biological Oxygen Demand	water	unspecified		**1.5E-06**	kg	2	1	1	3	1	2	1	1
	4	Chloride	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Sulfate	water	unspecified		**4.9E-05**	kg	2	1	1	3	1	2	1	1
	4	Phenol	water	unspecified		**2.5E-07**	kg	2	1	1	3	1	2	1	1
	4	Oils, unspecified	water	unspecified		**9.8E-07**	kg	2	1	1	3	1	2	1	1
	4	Dissolved organics	water	unspecified		**1.0E-04**	kg	2	1	1	3	1	2	1	1
	4	COD, Chemical Oxygen Demand	water	unspecified		**1.2E-05**	kg	2	1	1	3	1	2	1	1
	4	Suspended solids, unspecified	water	unspecified		**4.9E-06**	kg	2	1	1	3	1	2	1	1
	4	Sulfide	water	unspecified		**1.4E-07**	kg	2	1	1	3	1	2	1	1
	4	Ammonia	water	unspecified		**2.5E-06**	kg	2	1	1	3	1	2	1	1
5		Transport, lorry >16t, fleet average			RER	**0.21**	t*km	2	1	1	3	1	2	1	1
5		Transport, freight, rail 2011			CN	**0.62**	t*km	2	1	1	3	1	2	1	1

[1] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048 (Supplementary Materials S1-S6.)

Table A-33. Brush Wood, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Brush wood, at consumer			CN	**1.00**	kg								1
4		Energy, gross calorific value, in biomass	resource	biotic		**9.60**	MJ	1	1	4	1	2	4	5	1,2,3,4,5,6
4		Energy, gross calorific value, in biomass, primary forest	resource	biotic		**5.72**	MJ	1	1	4	1	2	4	5	1,2,3,4,5,6

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048 (Supplementary Materials S1-S6.)

[3] FAO (Food and Agriculture Organization). 2010. Global forest resources assessment 2010: main report. FAO Forestry Paper 163. Food and Agriculture Organization of the United Nations, Rome, Italy.

[4] Zhou, N., M.A., McNeil, and D. Fridley, et al. 2007. Energy use China: Sectoral trends and future outlook. Lawrence Berkeley National Laboratory, LBNL-61904.

[5] Tonooka Y., M. Hailin, and Y. Ning, et al. 2003. Energy consumption in residential house and emissions inventory of GHGs, air pollutants in China. Journal of Asian Architecture and Building Engineering 1: 1-8.

[6] Jingjing L, Z., Xing, P., DeLauil P, et al. 2001. Biomass energy in China and its potential. Energy for Sustainable Development V(4): 66-80.

Table A-34. Coal Briquette, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Coal briquette, at consumer			CN	**0.032**	kg								1
5		Transport, barge			RER	**0.126**	t*km	1	1	4	3	2	4	5	1
5		Transport, coal freight, rail 2011			CN	**1.04**	t*km	1	1	4	3	2	4	5	1
5		Transport, lorry >16t, fleet average			RER	**0.0069**	t*km	1	1	4	3	2	4	5	1
5		Hard coal briquettes, at plant 2011			CN	**1.00**	MJ	1	1	4	1	2	4	5	1

[1] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. Final report ecoinvent No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dubendorf, CH.

Table A-35. Coal Gas, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Coal gas, at consumer			CN	**1.00**	kg								1
5		Coal gas, high pressure, at consumer 2011			CN	**43.8**	MJ	1	1	4	1	2	4	5	2

[1] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. Final report ecoinvent No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dubendorf, CH.

[2] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

Table A-36. Coal Powder, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Coal powder, at consumer			CN	**1.00**	kg								
5		Hard coal supply mix, at regional storage 2011			CN	**1.00**	kg	1	1	4	1	2	4	5	1

[1] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. Final report ecoinvent No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dubendorf, CH.

Table A-37. Fuel Wood, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Fuel wood, at consumer			CN	**1.00**	kg								1
4		Energy, gross calorific value, in biomass	resource	biotic		**10.2**	MJ	1	1	4	1	2	4	5	1,2,3,4,5,6
4		Energy, gross calorific value, in biomass, primary forest	resource	biotic		**6.07**	MJ	1	1	4	1	2	4	5	1,2,3,4,5,6

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Singh P, H., Gundimeda, and M., Stucki. 2014a. Environmental footprint of cooking fuels: a life cycle assessment of ten fuel sources used in Indian households. International Journal of Life Cycle Assessment 19: 1036-1048.; Supplementary Materials S1-S6.

[3] FAO (Food and Agriculture Organization). 2010. Global forest resources assessment 2010: main report. FAO Forestry Paper 163. Food and Agriculture Organization of the United Nations, Rome, Italy.

[4] Zhou, N., M.A., McNeil, and D. Fridley, et al. 2007. Energy use China: Sectoral trends and future outlook. Lawrence Berkeley National Laboratory, LBNL-61904.

[5] Tonooka Y., M. Hailin, and Y. Ning, et al. 2003. Energy consumption in residential house and emissions inventory of GHGs, air pollutants in China. Journal of Asian Architecture and Building Engineering 1: 1-8.

[6] Jingjing L, Z., Xing, P., DeLauil P, et al. 2001. Biomass energy in China and its potential. Energy for Sustainable Development V(4): 66-80.

Table A-38. Kerosene, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Kerosene, at consumer			CN	**1.00**	kg								
5		Kerosene, at regional storage 2011			CN	**1.00**	kg	1	1	3	2	2	4	5	1

[1] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. Final report ecoinvent No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dubendorf, CH.

Table A-39. LPG At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	LPG, at consumer			CN	**1.00**	kg								
5		Bottling, LPG from natural gas, at plant			CN	**0.500**	kg	1	1	1	1	1	2	3	N/A
5		Bottling, LPG from crude oil, at plant			CN	**0.500**	kg	1	1	1	1	1	2	3	N/A

Table A-40. Maize Residue, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Maize residue, at consumer			CN	**1.00**	kg								1
4		Energy, gross calorific value, in biomass	resource	biotic		**16.1**	MJ	1	1	4	1	2	4	5	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

Table A-41. Natural Gas, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Natural gas, at consumer			CN	**1.00**	kg								2
5		Natural gas, high pressure, at consumer 2011			CN	**51.3**	MJ	1	1	4	1	2	4	5	1

[1] Dones, R., C., Bauer, and R., Bollinger, et al. 2007. Sachbilanzen von Energiesystemen: Grundlagen fur den okologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Okobilanzen fur die Schweiz. [Life cycle of energy systems: founde Schweiz. Final report ecoinvent No. 6-V, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH. Online: www.ecoinvent.ch.

[2] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

Table A-42. Rice Straw, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Rice straw, at consumer			CN	**1.00**	kg								1
4		Energy, gross calorific value, in biomass	resource	biotic		**18.0**	MJ	1	1	4	1	2	4	5	1

[1] Liu Z, A., Xu, and B. Long. 2011. Energy from combustion of rice straw: Status and challenges to China. Energy and Power Engineering 3(3): 325-331.

Table A-43. Wheat Residue, At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Wheat residue, at consumer			CN	**1.00**	kg								1
4		Energy, gross calorific value, in biomass	resource	biotic		**14.0**	MJ	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

Table A-44. Heat from Biomass Pellets; Pellet Stove; At Consumer

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from biomass pellets; pellet stove; at consumer			CN	**1.00**	MJ								
5		Biomass pellets, at consumer, national mix			CN	**0.12**	kg	1	1	2	3	1	4	5	4, 5, 6
	4	Carbon dioxide, biogenic	air	low population density		**0.26**	kg	1	1	2	3	1	4	5	1
	4	Carbon dioxide, fossil	air	low population density		**0.075**	kg	1	1	2	3	1	4	5	1
	4	Carbon monoxide	air	low population density		**2.0E-04**	kg	1	1	2	3	1	4	5	1
	4	Carbon monoxide, biogenic	air	low population density		**7.0E-04**	kg	1	1	2	3	1	4	5	1
	4	Methane, biogenic	air	low population density		**7.8E-05**	kg	1	1	2	3	1	4	5	1
	4	Methane, fossil	air	low population density		**2.2E-05**	kg	1	1	2	3	1	4	5	1
	4	Nitrogen oxides	air	low population density		**6.0E-05**	kg	1	1	2	3	1	4	5	2
	4	Particulates, < 2.5 um	air	low population density		**9.0E-05**	kg	1	1	2	3	1	4	5	1
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.0015**	kg	1	1	2	3	1	4	5	3

[1] Jetter, J., Y., Zhao, K.R., Smith, et al. 2012. Pollutant emissions and energy efficiency under controlled conditions for household biomass cookstoves and implications for metrics useful in setting international test standards. Environmental Science & Tecal test standards. Environmental Science & Technology, 46: 10827-10834.

[2] Boman, C. 2005. Particulate and gaseous emissions from residential biomass combustion. Ph.D thesis, Umea University, Umea, Sweden.

[3] Roy M.M., A., Dutta, and K., Corscadden. 2013. An experimental study of combustion and emissions of biomass pellets in a prototype pellet furnace. Applied Energy 108: 298-307.

[4] Jingjing L, Z., Xing, P., DeLauil P, et al. 2001. Biomass energy in China and its potential. Energy for Sustainable Development V(4): 66-80.

[5] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[6] Liu Z, A., Xu, and B. Long. 2011. Energy from combustion of rice straw: Status and challenges to China. Energy and Power Engineering 3(3): 325-331.

Table A-45. Heat from Biomass; Cookstove; At Consumer; National Mix (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
5		Heat from brush wood, brick stove with flue, at consumer			CN	0.16	MJ	1	1	1	1	2	4	4	1,2
5		Heat from brush wood, improved brick stove with flue, at consumer			CN	0.059	MJ	1	1	1	1	2	4	4	1,2
5		Heat from brush wood, India metal stove without flue, at consumer			CN	0.059	MJ	1	1	1	1	2	4	4	1,2
5		Heat from fuel wood, brick stove with flue, at consumer			CN	0.16	MJ	1	1	1	1	2	4	4	1,2
5		Heat from fuel wood, improved brick stove with flue, at consumer			CN	0.12	MJ	1	1	1	1	2	4	4	1,2
5		Heat from fuel wood, improved brick stove without flue, at consumer			CN	0.091	MJ	1	1	1	1	2	4	4	1,2
5		Heat from maize residue, brick stove with flue, at consumer			CN	0.12	MJ	1	1	1	1	2	4	4	1,2
5		Heat from maize residue, improved brick stove with flue, at consumer			CN	0.091	MJ	1	1	1	1	2	4	4	1,2
5		Heat from wheat residue, brick stove with flue, at consumer			CN	0.12	MJ	1	1	1	1	2	4	4	1,2
5		Heat from wheat residue, brick stove without flue, at consumer			CN	0.091	MJ	1	1	1	1	2	4	4	1,2
5		Heat from rice straw, improved brick stove with flue, at consumer			CN	0.025	MJ	1	1	1	1	2	4	4	1,2
	0	Heat from biomass; cookstove; at consumer; national mix			CN	1.00	MJ								1,2

[1] Dalberg Global Development Advisors. 2014. China stoves and fuels market assessment. Global Alliance for Clean Cookstoves. May presentation: preliminary findings, 19 May 2014.

[2] Jingjing L, Z., Xing, P., DeLauil P, et al. 2001. Biomass energy in China and its potential. Energy for Sustainable Development V(4): 66-80.

Table A-46. Heat from Brush Wood; Brick Stove With Flue; At Consumer (CN)

Input Group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from brush wood; brick stove with flue; at consumer			CN	1.00	MJ								1
4		Air, from nature	resource	air		0.29	kg	1	1	4	1	2	2	3	1
5		Brush wood, at consumer			CN	0.47	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		0.45	kg	1	1	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		0.27	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide	air	low population density		0.012	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		0.021	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		7.5E-04	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		4.4E-04	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		9.3E-04	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		5.4E-04	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		0.0013	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		2.4E-06	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		9.6E-05	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		3.5E-07	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		2.0E-07	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		6.7E-06	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		9.3E-05	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		1.8E-04	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		1.1E-06	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		8.1E-06	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		4.1E-07	kg	1	1	4	1	2	4	5	2

Table A-46. Heat from Brush Wood; Brick Stove With Flue; At Consumer (CN)

Input Group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	1-butylene	Air	low population density		9.6E-07	kg	1	1	4	1	2	4	5	2
	4	Butane	Air	low population density		2.8E-07	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	Air	low population density		3.1E-06	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	Air	low population density		1.4E-07	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	Air	low population density		1.6E-07	kg	1	1	4	1	2	4	5	2
	4	Toluene	Air	low population density		6.7E-06	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	Air	low population density		1.8E-07	kg	1	1	4	1	2	4	5	2
	4	Decane	Air	low population density		9.5E-05	kg	1	1	4	1	2	4	5	2
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	0.0083	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-47. Heat from Brush Wood; India Metal Stove Without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technologica	Uncertainty	Precision	References
	0	Heat from brush wood; India metal stove without flue; at consumer			CN	1.00	MJ								1
4		Air, from nature	resource	air		0.22	kg	1	1	4	1	2	2	3	
5		Brush wood, at consumer			CN	0.38	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		0.35	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		0.21	kg	1	4	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		0.024	kg	1	4	4	1	2	2	3	1
	4	Carbon monoxide	air	low population density		0.014	kg	1	4	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		0.0014	kg	1	4	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		8.1E-04	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		6.1E-04	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		0.0019	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		0.0017	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		9.2E-07	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		2.1E-04	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		2.8E-07	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		4.9E-06	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		2.0E-04	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		2.8E-04	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		1.8E-06	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		1.0E-05	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		1.4E-06	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		2.4E-07	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		3.1E-06	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		9.4E-06	kg	1	1	4	1	2	4	5	2
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	0.0067	kg	1	1	4	1	2	4	5	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-48. Heat from Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from coal briquette; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.27**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.27**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.42**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**5.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**7.5E-05**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.0054**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**2.9E-06**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**2.1E-06**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**4.9E-05**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**7.6E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**2.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**3.8E-08**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**5.3E-08**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**8.4E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**7.8E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.2E-08**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**8.6E-09**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.9E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**6.8E-09**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**6.3E-09**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**1.1E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**1.2E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**2.7E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.6E-09**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**2.7E-09**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**1.1E-09**	kg	1	1	4	1	2	4	5	2

Table A-48. Heat from Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	2-Methyl-2-butene	air	low population density		**3.5E-09**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**2.2E-10**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**4.3E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**3.1E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**3.9E-09**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**8.6E-09**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**1.3E-09**	kg	1	1	4	1	2	4	5	2
	4	2,4-Dimethylpentane	air	low population density		**1.1E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**2.1E-09**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**2.2E-10**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**3.4E-09**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**9.3E-09**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**4.6E-09**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**8.2E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**2.6E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Ethylhexane	air	low population density		**2.4E-09**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**8.5E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**2.2E-08**	kg	1	1	4	1	2	4	5	2
	4	Cumene	air	low population density		**5.7E-09**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**3.9E-08**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.11**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-49. Heat from Coal Briquette; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from coal briquette; metal stove without flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.21**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.19**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.31**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**2.3E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.9E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.004**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**4.0E-06**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.8E-05**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**6.3E-06**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.5E-06**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**6.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**3.4E-07**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**4.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**7.5E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**7.0E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**7.7E-08**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.7E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**6.1E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**5.6E-08**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2

Table A-49. Heat from Coal Briquette; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	iso-Pentane	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**2.4E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**9.1E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**2.4E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**3.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**3.8E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**2.8E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**3.5E-08**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**7.7E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**1.2E-08**	kg	1	1	4	1	2	4	5	2
	4	2,4-Dimethylpentane	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**1.9E-08**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**3.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**8.3E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**4.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**7.3E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**2.3E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Ethylhexane	air	low population density		**2.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**7.6E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**8.9E-08**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.9E-07**	kg	1	1	4	1	2	4	5	2

Table A-49. Heat from Coal Briquette; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	Cumene	air	low population density		**5.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**3.5E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.084**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-50. Heat from Coal Gas; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from coal gas; traditional gas stove without flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.043**	kg	1	1	4	1	2	2	3	
5		Coal gas, at consumer			CN	**0.050**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.093**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**8.3E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**8.9E-05**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**3.0E-08**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**9.8E-06**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**8.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**3.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**2.5E-08**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**4.7E-08**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**6.4E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.3E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**3.5E-08**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2

Table A-50. Heat from Coal Gas; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	2-Methylpentane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**8.5E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	N-propylbenzene	air	low population density		**1.5E-08**	kg	1	1	4	1	2	4	5	2
	4	para-Ethyltoluene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	meta-Ethyltoluene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1,2,4-Trimethylbenzene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-51. Heat from Coal Powder; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from coal powder; brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.39**	kg	1	1	4	1	2	2	3	
5		Coal powder, at consumer			CN	**0.22**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.54**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**5.6E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**5.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.044**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**2.7E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.5E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**4.3E-04**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**3.7E-06**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**4.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.7E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**7.9E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**5.5E-06**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**7.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**8.7E-08**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**2.7E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**6.6E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Butene	air	low population density		**2.5E-07**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**2.6E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**4.0E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**8.7E-08**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**9.6E-08**	kg	1	1	4	1	2	4	5	2

Table A-51. Heat from Coal Powder; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	trans-2-Pentene	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**1.8E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**8.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**5.8E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**5.2E-08**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**6.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**1.0E-06**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**4.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1,2,4-Trimethylbenzene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.015**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-52. Heat from Coal Powder; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	Heat from coal powder; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.58**	kg	1	1	4	1	2	2	3	
5		Coal powder, at consumer			CN	**0.21**	kg	1	4	4	1	2	3	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.74**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**1.2E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.2E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.026**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**0.0011**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**3.8E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0013**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**3.9E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**7.9E-06**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**3.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**2.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**0.00106**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**3.1E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**5.8E-05**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**1.7E-04**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**3.7E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**3.0E-05**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.6E-05**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**9.6E-06**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**8.4E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**2.8E-06**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**5.2E-07**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**9.0E-06**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2

Table A-52. Heat from Coal Powder; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	2-Methylpentane	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**5.3E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**4.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**6.2E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**1.6E-06**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**5.1E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**3.7E-07**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**3.7E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**4.2E-07**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**4.2E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**6.0E-05**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**4.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**3.7E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.015**	kg	1	1	4	1	2	3	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-53. Heat from Coal Powder; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from coal powder; metal stove without flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.43**	kg	1	1	4	1	2	4	5	
5		Coal powder, at consumer			CN	**0.26**	kg	1	4	4	1	2	4	5	1
	4	Carbon dioxide, fossil	air	low population density		**0.64**	kg	1	1	4	1	2	4	5	1
	4	Sulfur dioxide	air	low population density		**3.8E-05**	kg	1	1	4	1	2	4	5	1
	4	Nitrogen oxides	air	low population density		**3.9E-05**	kg	1	1	4	1	2	4	5	1
	4	Carbon monoxide, fossil	air	low population density		**0.018**	kg	1	1	4	1	2	4	5	1
	4	Methane, fossil	air	low population density		**0.0027**	kg	1	1	4	1	2	4	5	1
	4	Non methane total organic compounds	air	low population density		**6.2E-04**	kg	1	1	4	1	2	4	5	1
	4	Particulates, < 2.5 um	air	low population density		**0.0022**	kg	1	1	4	1	2	4	5	1
	4	Benzene	air	low population density		**6.4E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**1.3E-05**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**5.0E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**4.2E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**0.0017**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**5.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**9.4E-05**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**2.7E-04**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**6.1E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**4.9E-05**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**2.6E-05**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**1.6E-05**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**4.7E-06**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**8.5E-07**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**1.5E-05**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2

Table A-53. Heat from Coal Powder; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	2-Methylpentane	air	low population density		**3.0E-06**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**8.7E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**6.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**2.6E-06**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**8.3E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**6.0E-07**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**6.1E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**6.8E-07**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**2.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**6.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**9.8E-05**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**2.3E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**8.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**6.1E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.018**	kg	1	1	4	1	2	4	5	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-54. Heat from DME; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from DME; traditional gas stove without flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.016**	kg	1	1	4	1	2	2	3	
5		Bottling; DME from coal gas; at plant			CN	**0.077**	kg	1	4	4	1	2	2	3	1,3
	4	Carbon dioxide, fossil	air	low population density		**0.093**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**8.3E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**8.9E-05**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**3.0E-08**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**9.8E-06**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**8.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**3.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**2.5E-08**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**4.7E-08**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**6.4E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.3E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Butene	air	low population density		**3.5E-08**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**3.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2

Table A-54. Heat from DME; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	2-Methylpentane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**8.5E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**6.0E-09**	kg	1	1	4	1	2	4	5	2
	4	N-propylbenzene	air	low population density		**1.5E-08**	kg	1	1	4	1	2	4	5	2
	4	para-Ethyltoluene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	meta-Ethyltoluene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1,2,4-Trimethylbenzene	air	low population density		**1.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

[3] Larson, E., and H., Yang. 2004. Dimethyl ether (DME) from coal as a household cooking fuel in China. Energy for Sustainable Development VIII(3): 115-126.

Table A-55. Heat from Fuel Wood; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from fuel wood; brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.33**	kg	1	1	4	1	2	2	3	
5		Fuel wood, at consumer			CN	**0.47**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.49**	kg	1	1	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.29**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.0093**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide	air	low population density		**0.0056**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**7.8E-04**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**4.7E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**2.3E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**9.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0011**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**5.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**3.4E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**1.1E-05**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**1.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**3.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**1.4E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**6.8E-07**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**1.6E-06**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**4.6E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**5.1E-06**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Butene	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**2.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**1.1E-05**	kg	1	1	4	1	2	4	5	2

Table A-55. Heat from Fuel Wood; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	Ethyl benzene	air	low population density		**2.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**1.6E-04**	kg	1	1	4	1	2	4	5	2
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.0054**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-56. Heat from Fuel Wood; Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from fuel wood; improved brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.16**	kg	1	1	4	1	2	2	3	
5		Fuel wood, at consumer			CN	**0.26**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.25**	kg	1	1	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.15**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.011**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide	air	low population density		**0.0067**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**6.3E-04**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**3.7E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.4E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**0.0015**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0011**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**7.6E-06**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**2.2E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**3.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**1.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**2.2E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**8.0E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**1.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.9E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**2.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**7.4E-06**	kg	1	1	4	1	2	4	5	2
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.0030**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-57. Heat from Fuel Wood; Improved Brick Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from fuel wood; improved brick stove without flue; at consumer			CN	**1.00**	MJ								1
4		Air, from nature	resource	air		**0.25**	kg	1	1	4	1	2	2	3	
5		Fuel wood, at consumer			CN	**0.29**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.31**	kg	1	1	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.19**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.01**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide	air	low population density		**0.01**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**0.00**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**0.00**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**2.8E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**0.0019**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0015**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**7.1E-07**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**2.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**2.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**4.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethene	air	low population density		**2.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**2.8E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**3.0E-06**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**9.3E-06**	kg	1	1	4	1	2	4	5	2
5		Disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.0033**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-58. Heat from Honeycomb Coal Briquette; Improved Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from honeycomb coal briquette; improved metal stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.23**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.11**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.30**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**9.2E-06**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**4.9E-05**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.0065**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**6.2E-07**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**5.3E-05**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**1.5E-06**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**5.8E-08**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**2.2E-07**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**6.7E-08**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**1.7E-08**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**1.5E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**3.9E-08**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**1.3E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**3.7E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**2.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**2.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**4.2E-08**	kg	1	1	4	1	2	4	5	2

Table A-58. Heat from Honeycomb Coal Briquette; Improved Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	Ethyl benzene	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.9E-07**	kg	1	1	4	1	2	4	5	2
	4	1,2,4-Trimethylbenzene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**4.1E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.028**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-59. Heat from Honeycomb Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from honeycomb coal briquette; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.60**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.32**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.82**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**6.0E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.4E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.019**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**3.3E-06**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.1E-07**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**7.0E-05**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**8.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**2.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**4.9E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**4.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**5.8E-08**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**9.2E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.6E-08**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.4E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**9.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**1.3E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**1.2E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**2.5E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**1.0E-08**	kg	1	1	4	1	2	4	5	2

Table A-59. Heat from Honeycomb Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	3-Methylhexane	air	low population density		**2.4E-08**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	Heptane	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.9E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**3.3E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**4.6E-08**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	1,2,4-Trimethylbenzene	air	low population density		**6.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**1.8E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.082**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-60. Heat from Honeycomb Coal Briquette; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from honeycomb coal briquette; metal stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.42**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.22**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.57**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**2.6E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**9.7E-05**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.015**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**4.1E-06**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**5.9E-06**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**6.2E-05**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**2.6E-06**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**4.5E-07**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**1.6E-06**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**1.1E-06**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**3.5E-07**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**7.6E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**8.6E-08**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**7.3E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**4.3E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**4.3E-08**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2

Table A-60. Heat from Honeycomb Coal Briquette; Metal Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	Cyclopentane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**2.2E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**6.9E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.2E-07**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**6.3E-08**	kg	1	1	4	1	2	4	5	2
	4	2,4-Dimethylpentane	air	low population density		**8.6E-08**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**7.9E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**4.0E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Ethylhexane	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**1.2E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**3.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**4.1E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.056**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-61. Heat from Kerosene; Pressure Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from kerosene; pressure stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.11**	kg	1	1	4	1	2	2	3	
5		Kerosene, at consumer			CN	**0.050**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.16**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**5.8E-07**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**7.8E-05**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**3.8E-04**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**5.2E-07**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**2.1E-05**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**3.0E-06**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**1.5E-07**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**1.3E-05**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**6.6E-06**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**8.6E-08**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**2.3E-06**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**9.5E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**2.4E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**6.9E-07**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**1.5E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**5.7E-08**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**5.7E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**3.0E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**6.8E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**3.5E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**2.1E-08**	kg	1	1	4	1	2	4	5	2

Table A-61. Heat from Kerosene; Pressure Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	2-Methyl-2-butene	air	low population density		**2.8E-08**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentene	air	low population density		**4.8E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**3.0E-07**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**2.8E-09**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**4.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**9.5E-08**	kg	1	1	4	1	2	4	5	2
	4	2,3,4-Trimethylpentane	air	low population density		**1.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**5.5E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**3.0E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Ethylhexane	air	low population density		**5.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**8.2E-08**	kg	1	1	4	1	2	4	5	2
	4	Particulates, < 2.5 um	air	low population density		**8.7E-06**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-62. Heat from LPG; Infrared Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	Heat from LPG; infrared gas stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.11**	kg	1	1	4	1	2	2	3	
5		LPG, at consumer			CN	**0.048**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.15**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**1.3E-08**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**4.1E-06**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.0010**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**1.6E-05**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**2.4E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**5.4E-07**	kg	1	1	4	1	2	2	3	1
	4	1-butylene	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**3.2E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**7.9E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**3.2E-08**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**7.9E-09**	kg	1	1	4	1	2	4	5	2
	4	benzene	air	low population density		**5.5E-06**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**1.1E-08**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**3.7E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**2.2E-07**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**7.9E-09**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**5.4E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**1.7E-06**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**4.9E-08**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**6.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**2.5E-07**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.7E-07**	kg	1	1	4	1	2	4	5	2

Table A-62. Heat from LPG; Infrared Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	iso-Butene	air	low population density		**9.4E-08**	kg	1	1	4	1	2	4	5	2
	4	neopentane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**2.7E-07**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**3.7E-07**	kg	1	1	4	1	2	4	5	2
	4	styrene	air	low population density		**1.2E-05**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**2.2E-06**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**7.5E-08**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**3.7E-06**	kg	1	1	4	1	2	4	5	2

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-63. Heat from LPG; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from LPG; traditional gas stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.095**	kg	1	1	4	1	2	2	3	
5		LPG, at consumer			CN	**0.045**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.14**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.5E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**1.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**2.3E-05**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.5E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**2.5E-05**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**3.4E-06**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**2.3E-06**	kg	1	1	4	1	2	4	5	2
	4	styrene	air	low population density		**7.6E-06**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**3.1E-08**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**3.8E-08**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**7.1E-08**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**8.4E-08**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.0E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**5.9E-08**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**9.9E-08**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**2.3E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**4.7E-08**	kg	1	1	4	1	2	4	5	2
	4	neopentane	air	low population density		**6.9E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2

Table A-63. Heat from LPG; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	cis-2-Pentene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**2.0E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**2.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**3.4E-07**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.7E-07**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**1.1E-06**	kg	1	1	4	1	2	4	5	2

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-64. Heat from Maize Residue; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from maize residue; brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.17**	kg	1	1	4	1	2	2	3	
5		Maize residue, at consumer			CN	**0.57**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.67**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**8.0E-06**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**7.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.025**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**9.8E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**0.0019**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0010**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**5.2E-05**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**2.1E-05**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**1.5E-04**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**1.2E-04**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**2.6E-06**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**1.6E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**5.7E-07**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**2.4E-06**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**4.6E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**1.8E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**2.2E-07**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**2.9E-07**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2

Table A-64. Heat from Maize Residue; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	Octane	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
5		disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.035**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-65. Heat from Maize Residue; Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from maize residue; improved brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.076**	kg	1	1	4	1	2	2	3	
5		Maize residue, at consumer			CN	**0.33**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.35**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**6.5E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**2.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.029**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**0.0020**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**8.5E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0013**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**6.3E-05**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**5.2E-08**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**9.4E-06**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**1.1E-04**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**1.7E-04**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**4.2E-06**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**1.8E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**2.2E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**3.8E-06**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**6.9E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**2.6E-06**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**4.9E-07**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**1.1E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**4.5E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**9.1E-08**	kg	1	1	4	1	2	4	5	2

Table A-65. Heat from Maize Residue; Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	pentane	air	low population density		**1.5E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**2.0E-07**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**4.4E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**4.2E-07**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**8.0E-08**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**6.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**3.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**4.6E-08**	kg	1	1	4	1	2	4	5	2
5		disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.020**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-66. Heat from Natural Gas; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from natural gas; traditional gas stove without flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.089**	kg	1	1	4	1	2	2	3	
5		Natural gas, at consumer			CN	**0.036**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.13**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**5.4E-08**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**9.5E-06**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**3.3E-06**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**4.1E-06**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**6.4E-07**	kg	1	1	4	1	2	4	5	2
	4	styrene	air	low population density		**2.5E-08**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**2.9E-07**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**2.1E-07**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**4.3E-08**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**3.6E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**4.7E-08**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**5.0E-09**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**5.7E-08**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**2.0E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**1.5E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**4.4E-08**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**2.0E-08**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**1.2E-08**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2

Table A-66. Heat from Natural Gas; Traditional Gas Stove without Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	2-Methylhexane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**2.2E-08**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**7.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**6.3E-07**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**8.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**5.7E-08**	kg	1	1	4	1	2	4	5	2

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-67. Heat from Rice Straw; Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Data Quality: Complete-ness	Data Quality: Temporal	Data Quality: Geographic	Data Quality: Technological	Data Quality: Uncertainty	Data Quality: Precision	References
	0	Heat from rice straw; improved brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.092**	kg	1	1	4	1	2	2	3	
5		Rice straw, at consumer			CN	**0.29**	kg	1	4	4	1	2	2	3	3
	4	Carbon dioxide, biogenic	air	low population density		**0.35**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**6.5E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**2.0E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.029**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**0.0020**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**8.5E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0013**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**4.1E-06**	kg	2	2	3	1	3	5	5	2
	4	Xylene	air	low population density		**3.4E-09**	kg	2	2	3	1	3	5	5	2
	4	Ethane	air	low population density		**6.2E-07**	kg	2	2	3	1	3	5	5	2
	4	Ethane	air	low population density		**7.1E-06**	kg	2	2	3	1	3	5	5	2
	4	Ethyne	air	low population density		**1.1E-05**	kg	2	2	3	1	3	5	5	2
	4	Propane	air	low population density		**2.8E-07**	kg	2	2	3	1	3	5	5	2
	4	Propene	air	low population density		**1.2E-06**	kg	2	2	3	1	3	5	5	2
	4	iso-Butane	air	low population density		**1.4E-08**	kg	2	2	3	1	3	5	5	2
	4	iso-Butene	air	low population density		**8.1E-08**	kg	2	2	3	1	3	5	5	2
	4	1-butylene	air	low population density		**2.5E-07**	kg	2	2	3	1	3	5	5	2
	4	Butane	air	low population density		**4.5E-08**	kg	2	2	3	1	3	5	5	2
	4	trans-2-Butene	air	low population density		**1.7E-07**	kg	2	2	3	1	3	5	5	2
	4	cis-2-butene	air	low population density		**3.2E-08**	kg	2	2	3	1	3	5	5	2
	4	3-methyl-1-butene	air	low population density		**1.4E-08**	kg	2	2	3	1	3	5	5	2
	4	iso-Pentane	air	low population density		**7.2E-10**	kg	2	2	3	1	3	5	5	2

Table A-67. Heat from Rice Straw; Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	1-Pentene	air	low population density		**3.0E-08**	kg	2	2	3	1	3	5	5	2
	4	2-Methyl-1-butene	air	low population density		**6.0E-09**	kg	2	2	3	1	3	5	5	2
	4	Pentane	air	low population density		**9.9E-10**	kg	2	2	3	1	3	5	5	2
	4	trans-2-Pentene	air	low population density		**1.3E-08**	kg	2	2	3	1	3	5	5	2
	4	cis-2-Pentene	air	low population density		**8.6E-09**	kg	2	2	3	1	3	5	5	2
	4	2-Methyl-2-butene	air	low population density		**2.9E-08**	kg	2	2	3	1	3	5	5	2
	4	1-Hexene	air	low population density		**2.7E-08**	kg	2	2	3	1	3	5	5	2
	4	Hexane	air	low population density		**5.3E-09**	kg	2	2	3	1	3	5	5	2
	4	Heptane	air	low population density		**3.9E-09**	kg	2	2	3	1	3	5	5	2
	4	Toluene	air	low population density		**2.0E-07**	kg	2	2	3	1	3	5	5	2
	4	Ethyl benzene	air	low population density		**3.0E-09**	kg	2	2	3	1	3	5	5	2
5		disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.0020**	kg	1	1	4	1	2	2	3	1,3

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

[3] Liu Z, A., Xu, and B. Long. 2011. Energy from combustion of rice straw: Status and challenges to China. Energy and Power Engineering 3(3): 325-331.

Table A-68. Heat from Shanxi Coal Powder; Metal Stove with Flue; At Consumer (CN)

Flow Information	Output group	Flow	Category	Subcategory	Location	Amount		Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from Shanxi coal powder; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**1.03**	kg	1	1	4	1	2	2	3	
5		Coal powder, at consumer			CN	**0.70**	kg	1	4	4	1	2	3	3	1
	4	Carbon dioxide, fossil	air	low population density		**1.44**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**0.014**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**0.0027**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.060**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**0.0039**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.2E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**9.4E-05**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**1.2E-04**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**2.4E-06**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**9.4E-07**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**7.9E-05**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**3.3E-04**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**9.4E-05**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**1.8E-05**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**5.1E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.1E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**9.2E-06**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**4.9E-06**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**2.9E-06**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**2.6E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**8.7E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2

Table A-68. Heat from Shanxi Coal Powder; Metal Stove with Flue; At Consumer (CN)

Flow Information	Output group	Flow	Category	Subcategory	Location	Amount		Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	4	pentane	air	low population density		**2.8E-06**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**3.7E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**5.6E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**4.8E-07**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**4.0E-07**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**3.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**1.8E-05**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**4.3E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**1.5E-07**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.21**	kg	1	1	4	1	2	3	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-69. Heat from Shanxi Honeycomb Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality							References
								Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	
	0	Heat from Shanxi honeycomb coal briquette; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.20**	kg	1	1	4	1	2	2	3	
5		Coal briquette, at consumer			CN	**0.11**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.27**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**8.9E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.2E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.0077**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**4.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**1.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**7.2E-05**	kg	1	1	4	1	2	2	3	1
	4	1,2,4-Trimethylbenzene	air	low population density		**6.1E-04**	kg	1	1	4	1	2	4	5	2
	4	1-butene	air	low population density		**7.1E-06**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**1.5E-04**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**1.2E-05**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**2.4E-05**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	Benzene	air	low population density		**9.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Butane	air	low population density		**1.4E-05**	kg	1	1	4	1	2	4	5	2
	4	Decane	air	low population density		**1.8E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**2.8E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**5.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**4.6E-05**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**4.8E-04**	kg	1	1	4	1	2	4	5	2

Table A-69. Heat from Shanxi Honeycomb Coal Briquette; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	Heptane	air	low population density		**3.4E-05**	kg	1	1	4	1	2	4	5	2
	4	Hexane	air	low population density		**2.5E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.6E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**9.1E-06**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**1.9E-05**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**1.0E-04**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**3.3E-05**	kg	1	1	4	1	2	4	5	2
	4	Pentane	air	low population density		**1.3E-05**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**5.9E-05**	kg	1	1	4	1	2	4	5	2
	4	Propene	air	low population density		**9.3E-05**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**2.1E-04**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**1.0E-04**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**4.0E-02**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-70. Heat from Washed Coal Powder; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from washed coal powder; metal stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.55**	kg	1	1	4	1	2	2	3	
5		Coal powder, at consumer			CN	**0.36**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, fossil	air	low population density		**0.86**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**3.7E-04**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**6.3E-05**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, fossil	air	low population density		**0.032**	kg	1	1	4	1	2	2	3	1
	4	Methane, fossil	air	low population density		**0.0052**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**6.9E-04**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0052**	kg	1	1	4	1	2	2	3	1
	4	Benzene	air	low population density		**1.5E-04**	kg	1	1	4	1	2	4	5	2
	4	Butadiene	air	low population density		**4.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Xylene	air	low population density		**8.6E-07**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**3.7E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethane	air	low population density		**4.6E-04**	kg	1	1	4	1	2	4	5	2
	4	Ethyne	air	low population density		**1.3E-04**	kg	1	1	4	1	2	4	5	2
	4	Propane	air	low population density		**1.3E-04**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**1.7E-04**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**1.0E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**1.3E-05**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**3.7E-05**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**4.0E-05**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**5.9E-06**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**1.1E-06**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**3.0E-06**	kg	1	1	4	1	2	4	5	2
	4	iso-Pentane	air	low population density		**8.9E-06**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**3.6E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**2.7E-06**	kg	1	1	4	1	2	4	5	2

Table A-70. Heat from Washed Coal Powder; Metal Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	pentane	air	low population density		**2.3E-05**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**3.4E-07**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**3.0E-07**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentane	air	low population density		**1.4E-06**	kg	1	1	4	1	2	4	5	2
	4	2,3-Dimethybutane	air	low population density		**2.5E-06**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**6.0E-06**	kg	1	1	4	1	2	4	5	2
	4	3-Methylpentane	air	low population density		**1.6E-06**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**9.0E-06**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.6E-05**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclopentane	air	low population density		**4.4E-06**	kg	1	1	4	1	2	4	5	2
	4	Cyclohexane	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylhexane	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	2,3 Dimethylpentane	air	low population density		**1.9E-06**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**2.2E-06**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**1.1E-05**	kg	1	1	4	1	2	4	5	2
	4	Methyl cyclohexane	air	low population density		**2.0E-06**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**2.2E-05**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	3-Ethylhexane	air	low population density		**2.3E-07**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**3.2E-06**	kg	1	1	4	1	2	4	5	2
	4	Nonane	air	low population density		**3.3E-07**	kg	1	1	4	1	2	4	5	2
5		Disposal, lignite ash from stove, 0% water, to sanitary landfill			CN	**0.013**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-71. Heat from Wheat Residue; At Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	heat from wheat residue; at improved brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.13**	kg	1	1	4	1	2	2	3	
5		Wheat residue, at consumer			CN	**0.46**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.45**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**3.9E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**1.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.084**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**0.0042**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**0.0046**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0085**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**5.8E-04**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**5.0E-06**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**3.9E-05**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**7.9E-04**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**9.5E-04**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**8.5E-06**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**1.0E-04**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**4.0E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**5.3E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**1.3E-05**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**1.0E-06**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**1.8E-05**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**1.8E-06**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2

Table A-71. Heat from Wheat Residue; At Improved Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	iso-Pentane	air	low population density		**1.6E-07**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**2.0E-06**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**1.0E-06**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**4.1E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**1.0E-06**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**6.6E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**5.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentene	air	low population density		**1.8E-07**	kg	1	1	4	1	2	4	5	2
	4	4-Methyl-1-pentene	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**6.8E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**2.1E-06**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**1.3E-07**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**2.2E-08**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**5.8E-07**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**7.1E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**5.0E-05**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**3.4E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**3.4E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**3.3E-07**	kg	1	1	4	1	2	4	5	2
5		disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.040**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

Table A-72. Heat from Wheat Residue; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	0	Heat from wheat residue; brick stove with flue; at consumer			CN	**1.00**	MJ								1
4		air, from nature	resource	air		**0.36**	kg	1	1	4	1	2	2	3	
5		Wheat residue, at consumer			CN	**0.74**	kg	1	4	4	1	2	2	3	1
	4	Carbon dioxide, biogenic	air	low population density		**0.98**	kg	1	1	4	1	2	2	3	1
	4	Sulfur dioxide	air	low population density		**2.2E-05**	kg	1	1	4	1	2	2	3	1
	4	Nitrogen oxides	air	low population density		**8.1E-04**	kg	1	1	4	1	2	2	3	1
	4	Carbon monoxide, biogenic	air	low population density		**0.046**	kg	1	1	4	1	2	2	3	1
	4	Methane, biogenic	air	low population density		**0.0020**	kg	1	1	4	1	2	2	3	1
	4	Non methane total organic compounds	air	low population density		**0.0027**	kg	1	1	4	1	2	2	3	1
	4	Particulates, < 2.5 um	air	low population density		**0.0037**	kg	1	1	4	1	2	2	3	1
	4	benzene	air	low population density		**3.4E-04**	kg	1	1	4	1	2	4	5	2
	4	butadiene	air	low population density		**2.9E-06**	kg	1	1	4	1	2	4	5	2
	4	xylene	air	low population density		**7.4E-07**	kg	1	1	4	1	2	4	5	2
	4	ethane	air	low population density		**2.3E-05**	kg	1	1	4	1	2	4	5	2
	4	ethene	air	low population density		**4.7E-04**	kg	1	1	4	1	2	4	5	2
	4	ethyne	air	low population density		**5.6E-04**	kg	1	1	4	1	2	4	5	2
	4	propane	air	low population density		**5.0E-06**	kg	1	1	4	1	2	4	5	2
	4	propene	air	low population density		**6.1E-05**	kg	1	1	4	1	2	4	5	2
	4	iso-Butane	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	iso-Butene	air	low population density		**3.2E-06**	kg	1	1	4	1	2	4	5	2
	4	1-butylene	air	low population density		**7.8E-06**	kg	1	1	4	1	2	4	5	2
	4	butane	air	low population density		**6.2E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Butene	air	low population density		**1.1E-05**	kg	1	1	4	1	2	4	5	2
	4	cis-2-butene	air	low population density		**1.0E-06**	kg	1	1	4	1	2	4	5	2
	4	3-methyl-1-butene	air	low population density		**7.2E-07**	kg	1	1	4	1	2	4	5	2

Table A-72. Heat from Wheat Residue; Brick Stove with Flue; At Consumer (CN)

Input group	Output group	Flow	Category	Subcategory	Location	Amount	Unit	Data Quality: Reliability	Complete-ness	Temporal	Geographic	Technological	Uncertainty	Precision	References
	4	iso-Pentane	air	low population density		**9.2E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Pentene	air	low population density		**1.2E-06**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-1-butene	air	low population density		**6.0E-07**	kg	1	1	4	1	2	4	5	2
	4	pentane	air	low population density		**2.4E-07**	kg	1	1	4	1	2	4	5	2
	4	trans-2-Pentene	air	low population density		**6.0E-07**	kg	1	1	4	1	2	4	5	2
	4	cis-2-Pentene	air	low population density		**3.9E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methyl-2-butene	air	low population density		**3.2E-08**	kg	1	1	4	1	2	4	5	2
	4	Cyclopentene	air	low population density		**1.1E-07**	kg	1	1	4	1	2	4	5	2
	4	4-Methyl-1-pentene	air	low population density		**1.4E-07**	kg	1	1	4	1	2	4	5	2
	4	2-Methylpentane	air	low population density		**4.0E-08**	kg	1	1	4	1	2	4	5	2
	4	1-Hexene	air	low population density		**1.3E-06**	kg	1	1	4	1	2	4	5	2
	4	hexane	air	low population density		**7.9E-08**	kg	1	1	4	1	2	4	5	2
	4	3-Methylhexane	air	low population density		**1.3E-08**	kg	1	1	4	1	2	4	5	2
	4	2,2,4-Trimethylpentane	air	low population density		**3.4E-07**	kg	1	1	4	1	2	4	5	2
	4	heptane	air	low population density		**4.2E-08**	kg	1	1	4	1	2	4	5	2
	4	Toluene	air	low population density		**3.0E-05**	kg	1	1	4	1	2	4	5	2
	4	2-Methylheptane	air	low population density		**2.0E-08**	kg	1	1	4	1	2	4	5	2
	4	Octane	air	low population density		**2.0E-09**	kg	1	1	4	1	2	4	5	2
	4	Ethyl benzene	air	low population density		**2.0E-07**	kg	1	1	4	1	2	4	5	2
5		disposal, wood ash mixture, pure, 0% water, to landfarming			CN	**0.064**	kg	1	1	4	1	2	2	3	1

[1] Zhang J., K.R., Smith KR, and Y., Ma, et al. 2000. Greenhouse gases and other airborne pollutants from household stoves in China: a database for emission factors. Atmospheric Environment 34(26): 4537-4549.

[2] Tsai S.M., J., Zhang, and K.R. Smith, et al. 2003. Characterization of non-methane hydrocarbons emitted from various cookstoves used in China. Environmental Science & Technology 37(13): 2869-2877.

APPENDIX B: DETAILED LCA RESULTS TABLES

Appendix B provides detailed LCA results tables by impact category for India and China. Results for each country are included by cooking fuel type and by baseline and potential scenarios. Given the magnitude of impacts resulting from the use of cookstoves on both the environment and human health it is important to consider how future changes in cookstove fuel mix might affect these impacts. Eight potential fuel use scenarios were developed in order to explore how impacts in each of the ten studied environmental impact categories may change in the future.

Detailed Results Tables for India by Cooking Fuel Type

This section offers the detailed results tables by life cycle stage of the selected LCI and LCIA categories for the individual cooking fuels used within India (Table B-1 through Table B-10). Refer to Section 3.1, *Results for India by Cooking Fuel Type*, of the report for discussion and a visual of each table in this section.

Table B-1. Detailed Results for Global Climate Change Potential by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Global Climate Change Potential (kg CO_2 eq)	Hard Coal	16.2	0	1.62	945	**963**
	LPG from NG	3.13	2.77	12.0	274	**292**
	LPG from Oil	5.29	11.2	12.0	274	**303**
	Kerosene	6.54	13.9	12.7	148	**181**
	Electricity	0	0	0	415	**415**
	Sugarcane Ethanol	79.8	5.29	9.71	0.96	**95.7**
	Biogas from Cattle Dung	0	9.19	0	1.33	**10.5**
	Charcoal from Wood	0	274	29.0	270	**572**
	Biomass Pellets	0	27.8	1.10	105	**134**
	Firewood	0	0	0	539	**539**
	Crop Residue	0	0	0	132	**132**
	Dung Cake	0	0	0	191	**191**

Table B-2. Detailed Results for Cumulative Energy Demand by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		***Life Cycle Stage***				**TOTAL**
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Cumulative Energy Demand (MJ)	Hard Coal	7,315	0	10.8	6,452	**13,778**
	LPG from NG	18.1	44.3	27.0	1,302	**1,391**
	LPG from Oil	27.4	67.0	40.8	1,971	**2,106**
	Kerosene	33.6	93.2	28.8	2,428	**2,584**
	Electricity	0	0	0	5,443	**5,443**
	Sugarcane Ethanol	222	4,378	20.3	1,887	**6,507**
	Biogas from Cattle Dung	0	0	0	1,820	**1,820**
	Charcoal from Wood	0	4,494	0.39	5,715	**10,209**
	Biomass Pellets	0	189	3.01	1,847	**2,039**
	Firewood	0	0	0	7,716	**7,716**
	Crop Residue	0	0	0	9,670	**9,670**
	Dung Cake	0	0	0	12,859	**12,859**

Table B-3. Detailed Results for Fossil Depletion by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		***Life Cycle Stage***				**TOTAL**
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Fossil Depletion (kg oil eq)	Hard Coal	129	0	0.19	114	**243**
	LPG from NG	0.47	1.15	0.70	33.8	**36.1**
	LPG from Oil	0.70	1.71	1.04	50.2	**53.7**
	Kerosene	0.85	2.37	0.73	61.7	**65.7**
	Electricity	0	0	0	91.4	**91.4**
	Sugarcane Ethanol	12.2	2.80	3.30	0	**18.3**
	Biogas from Cattle Dung	0	0	0	0	**0**
	Charcoal from Wood	0	0.10	0.0094	0.0061	**0.12**
	Biomass Pellets	0	5.88	0.37	1.8E-04	**6.25**
	Firewood	0	0	0	0.0064	**0.0064**
	Crop Residue	0	0	0	0.0076	**0.0076**
	Dung Cake	0	0	0	0.15	**0.15**

Table B-4. Detailed Results for Water Depletion by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		Life Cycle Stage				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Water Depletion (m^3)	Hard Coal	0.38	0	8.53	7.70	**16.6**
	LPG from NG	0.74	1.25	24.7	0	**26.7**
	LPG from Oil	1.24	5.74	24.7	0	**31.7**
	Kerosene	1.53	7.09	27.7	0	**36.3**
	Electricity	0	0	0	515	**515**
	Sugarcane Ethanol	55.4	13.4	19.8	0	**88.6**
	Biogas from Cattle Dung	0	1.04	0	0	**1.04**
	Charcoal from Wood	0	0.58	9.0E-05	0.047	**0.63**
	Biomass Pellets	0	32.9	2.70	8.8E-04	**35.6**
	Firewood	0	0	0	0.049	**0.049**
	Crop Residue	0	0	0	0.058	**0.058**
	Dung Cake	0	0	0	1.19	**1.19**

Table B-5. Detailed Results for Particulate Matter Formation by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		Life Cycle Stage				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Particulate Matter Formation (kg PM10 eq)	Hard Coal	1.66	0	0.0038	17.6	**19.3**
	LPG from NG	0.0058	0.029	0.025	0.060	**0.12**
	LPG from Oil	0.010	0.070	0.025	0.060	**0.16**
	Kerosene	0.012	0.086	0.023	0.19	**0.31**
	Electricity	0	0	0	1.69	**1.69**
	Sugarcane Ethanol	0.11	0.035	0.018	4.3E-04	**0.17**
	Biogas from Cattle Dung	0	0	0	0.077	**0.077**
	Charcoal from Wood	0	18.8	0.050	0.70	**19.5**
	Biomass Pellets	0	0.11	0.0027	0.10	**0.21**
	Firewood	0	0	0	4.72	**4.72**
	Crop Residue	0	0	0	11.3	**11.3**
	Dung Cake	0	0	0	23.6	**23.6**

Table B-6. Detailed Results for Photochemical Oxidant Formation by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		Life Cycle Stage				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Photochemical Oxidant Formation (kg NMVOC eq)	Hard Coal	0.14	0	0.010	7.71	**7.86**
	LPG from NG	0.014	0.022	0.079	0.50	**0.62**
	LPG from Oil	0.024	0.15	0.079	0.50	**0.76**
	Kerosene	0.029	0.18	0.083	0.86	**1.16**
	Electricity	0	0	0	2.01	**2.01**
	Sugarcane Ethanol	0.17	0.047	0.064	0.062	**0.34**
	Biogas from Cattle Dung	0	0.0037	0	0.11	**0.11**
	Charcoal from Wood	0	5.30	0.21	5.03	**10.5**
	Biomass Pellets	0	0.13	0.0096	0.10	**0.24**
	Firewood	0	0	0	6.02	**6.02**
	Crop Residue	0	0	0	8.75	**8.75**
	Dung Cake	0	0	0	18.7	**18.7**

Table B-7. Detailed Results for Freshwater Eutrophication by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		Life Cycle Stage				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Freshwater Eutrophication (kg P eq)	Hard Coal	7.6E-06	0	0.0011	0.0010	**0.0021**
	LPG from NG	8.6E-06	2.0E-05	5.2E-04	0.0015	**0.0021**
	LPG from Oil	1.4E-05	7.9E-04	5.2E-04	0.0015	**0.0029**
	Kerosene	1.8E-05	9.7E-04	0.0023	0	**0.0033**
	Electricity	0	0	0	0.0034	**0.0034**
	Sugarcane Ethanol	0.033	0.0021	0.0016	1.1E-06	**0.037**
	Biogas from Cattle Dung	0	0	0	0	**0**
	Charcoal from Wood	0	0.13	1.0E-07	0.15	**0.28**
	Biomass Pellets	0	2.7E-04	3.1E-04	0.0028	**0.0034**
	Firewood	0	0	0	0.16	**0.16**
	Crop Residue	0	0	0	0.19	**0.19**
	Dung Cake	0	0	0	3.82	**3.82**

Table B-8. Detailed Results for Terrestrial Acidification by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Terrestrial Acidification (kg SO_2 eq)	Hard Coal	0.076	0	0.0094	1.78	**1.87**
	LPG from NG	0.011	0.12	0.056	0.12	**0.31**
	LPG from Oil	0.018	0.14	0.056	0.12	**0.33**
	Kerosene	0.023	0.17	0.052	0.16	**0.40**
	Electricity	0	0	0	4.00	**4.00**
	Sugarcane Ethanol	0.31	0.15	0.039	0	**0.50**
	Biogas from Cattle Dung	0	0	0	0.11	**0.11**
	Charcoal from Wood	0	0.0046	0	0.20	**0.21**
	Biomass Pellets	0	0.25	0.0063	0.034	**0.29**
	Firewood	0	0	0	0.40	**0.40**
	Crop Residue	0	0	0	0.62	**0.62**
	Dung Cake	0	0	0	0.75	**0.75**

Table B-9. Detailed Results for Ozone Depletion by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Ozone Depletion (kg CFC 11 eq)	Hard Coal	8.1E-09	0	1.1E-07	7.0E-07	**8.2E-07**
	LPG from NG	6.4E-09	1.2E-06	1.1E-06	0	**2.3E-06**
	LPG from Oil	1.1E-08	8.5E-07	1.1E-06	0	**2.0E-06**
	Kerosene	1.3E-08	1.0E-06	1.4E-06	0	**2.4E-06**
	Electricity	0	0	0	1.4E-06	**1.4E-06**
	Sugarcane Ethanol	4.6E-06	6.9E-07	1.0E-06	0	**6.3E-06**
	Biogas from Cattle Dung	0	0	0	0	**0**
	Charcoal from Wood	0	2.1E-09	0	2.5E-09	**4.5E-09**
	Biomass Pellets	0	1.7E-07	1.5E-07	4.6E-11	**3.2E-07**
	Firewood	0	0	0	2.6E-09	**2.6E-09**
	Crop Residue	0	0	0	3.1E-09	**3.1E-09**
	Dung Cake	0	0	0	6.2E-08	**6.2E-08**

Table B-10. Detailed Results for Black Carbon by Cooking Fuel Type in India

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Black Carbon & Short Lived Climate Pollutants (kg BC eq)	Hard Coal	0.34	0	1.3E-05	3.58	**3.91**
	LPG from NG	3.6E-04	-0.0061	8.1E-04	0.0055	**5.5E-04**
	LPG from Oil	6.2E-04	0.0072	8.1E-04	0.0055	**0.014**
	Kerosene	7.6E-04	0.0089	0.0010	0.034	**0.045**
	Electricity	0	0	0	-0.019	**-0.019**
	Sugarcane Ethanol	-0.0017	-0.0073	8.1E-04	0.0028	**-0.0054**
	Biogas from Cattle Dung	0	0	0	0.0068	**0.0068**
	Charcoal from Wood	0	4.02	0	0.26	**4.27**
	Biomass Pellets	0	-0.0010	8.9E-05	0.021	**0.020**
	Firewood	0	0	0	1.04	**1.04**
	Crop Residue	0	0	0	2.42	**2.42**
	Dung Cake	0	0	0	5.01	**5.01**

Detailed Results Tables for China by Cooking Fuel Type

This section provides ten tables with detailed results analysis of LCI and LCIA categories for the individual fuels used within China (Table B-11 through Table B-20). Refer to Section 4.1, *Results for China by Cooking Fuel Type*, of the report for discussion and a visual of each table in this section.

Table B-11. Detailed Results for Global Climate Change by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Global Climate Change (kg CO_2 eq)	Coal Mix	212	8.80	95.3	699	**1,014**
	Coal Powder	310	3.16	2.60	974	**1,289**
	Coal Briquettes	72.3	15.3	336	361	**784**
	Honeycomb Coal Briquettes	154	13.5	40.1	487	**695**
	Biomass Mix	0	0	0	180	**180**
	Fuel & Brush Wood	0	0	0	281	**281**
	Ag Residues	0	0	0	54.7	**54.7**
	LPG	22.6	1.35	19.1	145	**188**
	Kerosene	33.4	12.6	1.30	160	**207**
	Electricity	0	0	0	496	**496**
	Natural Gas	9.33	30.1	27.1	147	**213**
	Biomass Pellets	0	40.9	0	77.3	**118**
	DME	148	37.9	67.8	92.0	**345**

Table B-12. Detailed Results for Cumulative Energy Demand by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Cumulative Energy Demand (MJ)	Coal Mix	5,061	1,014	772	3,658	**10,506**
	Coal Powder	6,149	1,232	938	4,445	**12,764**
	Coal Briquettes	4,303	862	657	3,110	**8,932**
	Honeycomb Coal Briquettes	3,643	730	556	2,633	**7,563**
	Biomass Mix	0	0	0	7,151	**7,151**
	Fuel & Brush Wood	0	0	0	6,538	**6,538**
	Ag Residues	0	0	0	7,905	**7,905**
	LPG	278	197	18.4	2,291	**2,784**
	Kerosene	714	5.00	18.5	2,205	**2,943**
	Electricity	0	0	0	6,060	**6,060**
	Natural Gas	61.5	4.92	322	1,660	**2,049**
	Biomass Pellets	0	565	22.8	1,781	**2,369**
	DME	3,546	10.2	665	2,174	**6,395**

Table B-13. Detailed Results for Fossil Depletion by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Fossil Depletion (kg oil eq)	Coal Mix	86.4	17.3	13.2	62.5	**179**
	Coal Powder	103	20.6	15.7	74.2	**213**
	Coal Briquettes	76.0	15.2	11.6	54.9	**158**
	Honeycomb Coal Briquettes	64.3	12.9	9.82	46.5	**134**
	Biomass Mix	0	0	0	0.0082	**0.0082**
	Fuel & Brush Wood	0	0	0	0.0025	**0.0025**
	Ag Residues	0	0	0	0.015	**0.015**
	LPG	6.44	4.55	0.43	53.0	**64.4**
	Kerosene	16.4	0.12	0.43	50.7	**67.7**
	Electricity	0	0	0	95.6	**95.6**
	Natural Gas	1.46	0.12	7.65	39.4	**48.6**
	Biomass Pellets	0	8.09	0.030	1.8E-04	**8.12**
	DME	61.6	0.18	11.5	37.8	**111**

Table B-14. Detailed Results for Water Depletion by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Water Depletion (m^3)	Coal Mix	9.45	7.83	23.9	3.36	**44.5**
	Coal Powder	10.1	3.84	2.69	2.49	**19.1**
	Coal Briquettes	9.57	11.3	48.8	6.68	**76.3**
	Honeycomb Coal Briquettes	8.11	12.4	41.4	1.78	**63.7**
	Biomass Mix	0	0	0	0.063	**0.063**
	Fuel & Brush Wood	0	0	0	0.019	**0.019**
	Ag Residues	0	0	0	0.12	**0.12**
	LPG	53.9	1.61	1.56	0	**57.1**
	Kerosene	7.00	63.5	1.76	0	**72.3**
	Electricity	0	0	0	524	**524**
	Natural Gas	3.50	0.20	2.07	0	**5.77**
	Biomass Pellets	0	49.2	0	0.0049	**49.2**
	DME	20.4	3.03	4.11	0	**27.5**

Table B-15. Detailed Results for Particulate Matter Formation by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	**Fuel Processing**	**Distribution**	**Cookstove Use**	
Particulate Matter Formation (kg PM10 eq)	Coal Mix	0.23	0.12	0.070	1.39	**1.81**
	Coal Powder	0.29	0.0087	0.0079	2.66	**2.96**
	Coal Briquettes	0.18	0.25	0.14	0.11	**0.68**
	Honeycomb Coal Briquettes	0.15	0.22	0.12	0.14	**0.63**
	Biomass Mix	0	0	0	2.34	**2.34**
	Fuel & Brush Wood	0	0	0	1.49	**1.49**
	Ag Residues	0	0	0	3.40	**3.40**
	LPG	0.16	0.0037	0.0030	0.032	**0.20**
	Kerosene	0.21	0.0011	0.0043	0.018	**0.23**
	Electricity	0	0	0	1.33	**1.33**
	Natural Gas	0.019	6.8E-04	0.018	0.019	**0.057**
	Biomass Pellets	0	0.11	0	0.10	**0.21**
	DME	0.66	0.0068	0.036	0.046	**0.75**

Table B-16. Detailed Results for Photochemical Oxidant Formation by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		Life Cycle Stage: Feedstock Production	Life Cycle Stage: Fuel Processing	Life Cycle Stage: Distribution	Life Cycle Stage: Cookstove Use	TOTAL
Photochemical Oxidant Formation (kg NMVOC eq)	Coal Mix	0.21	0.041	0.27	1.80	**2.33**
	Coal Powder	0.26	0.012	0.031	3.00	**3.31**
	Coal Briquettes	0.18	0.071	0.56	0.39	**1.20**
	Honeycomb Coal Briquettes	0.15	0.067	0.47	0.81	**1.50**
	Biomass Mix	0	0	0	2.13	**2.13**
	Fuel & Brush Wood	0	0	0	1.81	**1.81**
	Ag Residues	0	0	0	2.52	**2.52**
	LPG	0.27	0.0052	0.017	0.11	**0.40**
	Kerosene	0.34	0.0020	0.0088	0.073	**0.42**
	Electricity	0	0	0	1.87	**1.87**
	Natural Gas	0.077	7.6E-04	0.081	0.066	**0.23**
	Biomass Pellets	0	0.16	0	0.10	**0.26**
	DME	0.17	0.010	1.73	0.095	**2.01**

Table B-17. Detailed Results for Freshwater Eutrophication by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		Life Cycle Stage: Feedstock Production	Life Cycle Stage: Fuel Processing	Life Cycle Stage: Distribution	Life Cycle Stage: Cookstove Use	TOTAL
Freshwater Eutrophication (kg P eq)	Coal Mix	0.10	0.0021	0.0028	4.3E-04	**0.11**
	Coal Powder	0.14	4.1E-04	3.1E-04	3.2E-04	**0.14**
	Coal Briquettes	0.079	0.0040	0.0057	8.6E-04	**0.089**
	Honeycomb Coal Briquettes	0.067	0.0037	0.0049	2.3E-04	**0.076**
	Biomass Mix	0	0	0	0.20	**0.20**
	Fuel & Brush Wood	0	0	0	0.061	**0.061**
	Ag Residues	0	0	0	0.38	**0.38**
	LPG	0.0078	1.7E-04	1.2E-04	0	**0.0080**
	Kerosene	0.010	5.1E-05	2.0E-04	0	**0.010**
	Electricity	0	0	0	0.063	**0.063**
	Natural Gas	3.1E-04	2.1E-05	3.6E-04	0	**6.8E-04**
	Biomass Pellets	0	0.0052	0	0.015	**0.020**
	DME	0.062	3.2E-04	7.4E-04	0	**0.063**

Table B- 18. Detailed Results for Terrestrial Acidification by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Terrestrial Acidification (kg SO_2 eq)	Coal Mix	1.03	0.077	0.17	2.45	**3.72**
	Coal Powder	1.32	0.028	0.019	4.57	**5.94**
	Coal Briquettes	0.79	0.13	0.35	0.32	**1.60**
	Honeycomb Coal Briquettes	0.67	0.12	0.30	0.34	**1.42**
	Biomass Mix	0	0	0	0.29	**0.29**
	Fuel & Brush Wood	0	0	0	0.29	**0.29**
	Ag Residues	0	0	0	0.30	**0.30**
	LPG	0.62	0.012	0.0072	0.046	**0.68**
	Kerosene	0.82	0.0035	0.013	0.030	**0.87**
	Electricity	0	0	0	4.27	**4.27**
	Natural Gas	0.083	0.0014	0.049	0.036	**0.17**
	Biomass Pellets	0	0.36	0	0.034	**0.39**
	DME	0.93	0.022	0.098	0.13	**1.18**

Table B-19. Detailed Results for Ozone Depletion by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Ozone Depletion (kg CFC 11 eq)	Coal Mix	1.1E-06	2.4E-06	2.3E-06	5.8E-07	**6.4E-06**
	Coal Powder	3.0E-07	1.8E-08	2.9E-07	2.3E-07	**8.4E-07**
	Coal Briquettes	3.5E-07	6.7E-06	5.3E-06	6.1E-07	**1.3E-05**
	Honeycomb Coal Briquettes	3.3E-06	2.9E-06	3.4E-06	1.3E-06	**1.1E-05**
	Biomass Mix	0	0	0	3.3E-09	**3.3E-09**
	Fuel & Brush Wood	0	0	0	9.9E-10	**9.9E-10**
	Ag Residues	0	0	0	6.2E-09	**6.2E-09**
	LPG	2.9E-05	5.9E-09	1.6E-07	0	**2.9E-05**
	Kerosene	3.8E-05	0	8.8E-08	0	**3.8E-05**
	Electricity	0	0	0	2.3E-06	**2.3E-06**
	Natural Gas	3.2E-05	2.7E-08	2.5E-06	0	**3.4E-05**
	Biomass Pellets	0	2.3E-07	0	2.3E-10	**2.3E-07**
	DME	2.1E-05	6.2E-08	2.1E-06	0	**2.3E-05**

Table B-20. Detailed Results for Black Carbon by Cooking Fuel Type in China

Per GJ Delivered Heat for Cooking		*Life Cycle Stage*				TOTAL
		Feedstock Production	Fuel Processing	Distribution	Cookstove Use	
Black Carbon & Short Lived Climate Pollutants (kg BC eq)	Coal Mix	-0.0045	0.038	0.017	-0.0067	**0.043**
	Coal Powder	-0.0043	0.036	0.016	-0.0064	**0.041**
	Coal Briquettes	-0.0049	0.041	0.018	-0.0072	**0.047**
	Honeycomb Coal Briquettes	-0.0046	0.038	0.017	-0.0068	**0.044**
	Biomass Mix	0	0	0	0.47	**0.47**
	Fuel & Brush Wood	0	0	0	0.30	**0.30**
	Ag Residues	0	0	0	0.69	**0.69**
	LPG	0.0028	-0.019	-0.0062	0.0046	**-0.018**
	Kerosene	-0.029	-0.0047	-2.3E-04	0.0023	**-0.032**
	Electricity	0	0	0	-0.12	**-0.12**
	Natural Gas	-0.0037	5.1E-05	-7.2E-05	0.0015	**-0.0022**
	Biomass Pellets	0	-0.010	1.4E-04	0.021	**0.011**
	DME	-0.031	0.087	-6.9E-04	-0.0022	**0.054**

Detailed LCA Results Tables for India by Baseline and Potential Scenarios

This section offers the detailed results tables by baseline and potential scenarios of the selected LCI and LCIA categories for the individual cooking fuels used within India (Table B-21 through Table B-29). Refer to Section 3.2, *Results for India by Baseline and Potential Scenarios*, of the report for discussion and a visual of each table in this section.

Table B-21. Detailed Results for Global Climate Change Potential by Baseline and Potential Scenarios in India

Global Climate Change Potential (kg CO_2 eq)/GJ Heat Delivered for Cooking									
Fuels:	Increase of Electrical Use in Urban	Increase of LPG in Urban	Increase in LPG/ Decrease in Biomass in both Urban and Rural	Increase in LPG/ Decrease in Biomass & Dung in Rural	Cleaner Electrical Grid with Increase in Urban	Increased Biomass Pellets/ Decreased Biomass & Dung	Increased Ethanol/ Decreased Biomass & Dung	Increased Biogas/ Decreased Biomass & Dung	Current Cookstove Fuel Use
Hard Coal	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3
LPG from NG	15.4	21.6	27.7	27.7	15.4	15.4	15.4	15.4	15.4
LPG from Oil	60.2	84.1	108	108	60.2	60.2	60.2	60.2	60.2
Kerosene	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80
Electricity	43.1	1.66	1.66	1.66	38.7	1.66	1.66	1.66	1.66
Sugarcane Ethanol	0	0	0	0	0	0	9.57	0	0
Biogas from Cattle Dung	0.042	0.042	0.042	0.042	0.042	0.042	0.042	1.09	0.042
Charcoal from Wood	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29

Table B-21. Detailed Results for Global Climate Change Potential by Baseline and Potential Scenarios in India

Global Climate Change Potential (kg CO_2 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Biomass Pellets	0	0	0	0	0	13.4	0	0	0
Firewood	219	219	174	197	219	242	242	242	264
Crop Residue	9.49	9.49	7.51	8.50	9.49	10.5	10.5	10.5	11.8
Dung Cake	20.2	20.2	20.2	10.7	20.2	10.7	10.7	10.7	20.2
TOTAL	394	383	365	380	390	381	377	368	400

Table B-22. Detailed Results for Cumulative Energy Demand by Baseline and Potential Scenarios in India

Cumulative Energy Demand (MJ)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	262	262	262	262	262	262	262	262	262
LPG from NG	73.6	103	132	132	73.6	73.6	73.6	73.6	73.6
LPG from Oil	419	586	752	752	419	419	419	419	419
Kerosene	82.7	82.7	82.7	82.7	82.7	82.7	82.7	82.7	82.7
Electricity	566	21.8	21.8	21.8	546	21.8	21.8	21.8	21.8
Sugarcane Ethanol	0	0	0	0	0	0	651	0	0
Biogas from Cattle Dung	7.28	7.28	7.28	7.28	7.28	7.28	7.28	189	7.28
Charcoal from Wood	40.8	40.8	40.8	40.8	40.8	40.8	40.8	40.8	40.8
Biomass Pellets	0	0	0	0	0	204	0	0	0
Firewood	3,142	3,142	2,486	2,814	3,142	3,470	3,470	3,470	3,781
Crop Residue	695	695	550	622	695	767	767	767	861
Dung Cake	1,363	1,363	1,363	720	1,363	720	720	720	1,363
TOTAL	6,651	6,302	6,912	5,454	6,631	6,068	6,515	6,046	6,912

Table B-23. Detailed Results for Fossil Depletion by Baseline and Potential Scenarios in India

Fossil Depletion (kg oil eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61	4.61
LPG from NG	1.91	2.67	3.42	3.42	1.91	1.91	1.91	1.91	1.91
LPG from Oil	10.7	14.9	19.2	19.2	10.7	10.7	10.7	10.7	10.7
Kerosene	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
Electricity	9.51	0.37	0.37	0.37	8.98	0.37	0.37	0.37	0.37
Sugarcane Ethanol	0	0	0	0	0	0	1.83	0	0
Biogas from Cattle Dung	0	0	0	0	0	0	0	0	0
Charcoal from Wood	4.7E-04	4.7E-04	4.7E-04	4.7E-04	4.7E-04	4.7E-04	4.7E-04	4.7E-04	4.7E-04
Biomass Pellets	0	0	0	0	0	0.63	0	0	0
Firewood	0.0026	0.0026	0.0020	0.0023	0.0026	0.0029	0.0029	0.0029	0.0031
Crop Residue	5.4E-04	5.4E-04	4.3E-04	4.9E-04	5.4E-04	6.0E-04	6.0E-04	6.0E-04	6.7E-04
Dung Cake	0.016	0.016	0.016	0.0087	0.016	0.0087	0.0087	0.0087	0.016
TOTAL	28.8	24.7	29.7	29.7	28.3	20.3	21.5	19.7	19.7

Table B-24. Detailed Results for Water Depletion by Baseline and Potential Scenarios in India

Water Depletion (m^3)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
LPG from NG	1.41	1.98	2.54	2.54	1.41	1.41	1.41	1.41	1.41
LPG from Oil	6.32	8.82	11.3	11.3	6.32	6.32	6.32	6.32	6.32
Kerosene	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Electricity	53.5	2.06	2.06	2.06	67.0	2.06	2.06	2.06	2.06
Sugarcane Ethanol	0	0	0	0	0	0	8.86	0	0
Biogas from Cattle Dung	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.11	0.0042
Charcoal from Wood	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Biomass Pellets	0	0	0	0	0	3.56	0	0	0
Firewood	0.020	0.020	0.016	0.018	0.020	0.022	0.022	0.022	0.024
Crop Residue	0.0042	0.0042	0.0033	0.0037	0.0042	0.0046	0.0046	0.0046	0.0052

Table B-24. Detailed Results for Water Depletion by Baseline and Potential Scenarios in India

Water Depletion (m^3)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Dung Cake	0.13	0.13	0.13	0.066	0.13	0.066	0.066	0.066	0.13
TOTAL	62.9	14.5	17.6	17.5	76.4	14.9	20.2	11.5	11.4

Table B-25. Detailed Results for Particulate Matter Formation by Baseline and Potential Scenarios in India

Particulate Matter Formation (kg PM10 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
LPG from NG	0.0063	0.0088	0.011	0.011	0.0063	0.0063	0.0063	0.0063	0.0063
LPG from Oil	0.033	0.046	0.059	0.059	0.033	0.033	0.033	0.033	0.033
Kerosene	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099
Electricity	0.18	0.0067	0.0067	0.0067	0.15	0.0067	0.0067	0.0067	0.0067
Sugarcane Ethanol	0	0	0	0	0	0	0.017	0	0
Biogas from Cattle Dung	3.1E-04	3.1E-04	3.1E-04	3.1E-04	3.1E-04	3.1E-04	3.1E-04	0.0080	3.1E-04
Charcoal from Wood	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
Biomass Pellets	0	0	0	0	0	0.021	0	0	0
Firewood	1.92	1.92	1.52	1.72	1.92	2.12	2.12	2.12	2.31
Crop Residue	0.81	0.81	0.64	0.73	0.81	0.90	0.90	0.90	1.01
Dung Cake	2.51	2.51	2.51	1.32	2.51	1.32	1.32	1.32	2.51
TOTAL	5.91	5.76	5.20	4.30	5.88	4.87	4.86	4.85	6.33

Table B-26. Detailed Results for Photochemical Oxidant Formation by Baseline and Potential Scenarios in India

Photochemical Oxidant Formation (kg NMVOC eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
LPG from NG	0.033	0.046	0.059	0.059	0.033	0.033	0.033	0.033	0.033
LPG from Oil	0.15	0.21	0.27	0.27	0.15	0.15	0.15	0.15	0.15
Kerosene	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
Electricity	0.21	0.0081	0.0081	0.0081	0.17	0.0081	0.0081	0.0081	0.0081
Sugarcane Ethanol	0	0	0	0	0	0	0.034	0	0
Biogas from Cattle Dung	4.5E-04	4.5E-04	4.5E-04	4.5E-04	4.5E-04	4.5E-04	4.5E-04	0.012	4.5E-04
Charcoal from Wood	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
Biomass Pellets	0	0	0	0	0	0.024	0	0	0
Firewood	2.45	2.45	1.94	2.19	2.45	2.71	2.71	2.71	2.95
Crop Residue	0.63	0.63	0.50	0.56	0.63	0.69	0.69	0.69	0.78
Dung Cake	1.98	1.98	1.98	1.05	1.98	1.05	1.05	1.05	1.98
TOTAL	5.68	5.55	4.98	4.37	5.64	4.89	4.90	4.88	6.13

Table B-27. Detailed Results for Freshwater Eutrophication by Baseline and Potential Scenarios in India

Freshwater Eutrophication (kg P eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	4.1E-05	4.1E-05	4.1E-05	4.1E-05	4.1E-05	4.1E-05	4.1E-05	4.1E-05	4.1E-05
LPG from NG	1.1E-04	1.6E-04	2.0E-04	2.0E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04
LPG from Oil	5.7E-04	8.0E-04	0.0010	0.0010	5.7E-04	5.7E-04	5.7E-04	5.7E-04	5.7E-04
Kerosene	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04
Electricity	3.5E-04	1.4E-05	1.4E-05	1.4E-05	3.2E-04	1.4E-05	1.4E-05	1.4E-05	1.4E-05
Sugarcane Ethanol	0	0	0	0	0	0	0.0037	0	0
Biogas from Cattle Dung	0	0	0	0	0	0	0	0	0
Charcoal from Wood	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
Biomass Pellets	0	0	0	0	0	3.4E-04	0	0	0
Firewood	0.064	0.064	0.051	0.057	0.064	0.071	0.071	0.071	0.077
Crop Residue	0.013	0.013	0.011	0.012	0.013	0.015	0.015	0.015	0.017

Table B-27. Detailed Results for Freshwater Eutrophication by Baseline and Potential Scenarios in India

Freshwater Eutrophication (kg P eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Dung Cake	0.40	0.40	0.40	0.21	0.40	0.21	0.21	0.21	0.40
TOTAL	0.48	0.48	0.47	0.29	0.48	0.30	0.31	0.30	0.50

Table B-28. Detailed Results for Terrestrial Acidification by Baseline and Potential Scenarios in India

Terrestrial Acidification (kg SO_2 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
LPG from NG	0.016	0.023	0.029	0.029	0.016	0.016	0.016	0.016	0.016
LPG from Oil	0.065	0.091	0.12	0.12	0.065	0.065	0.065	0.065	0.065
Kerosene	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
Electricity	0.42	0.016	0.016	0.016	0.35	0.016	0.016	0.016	0.016
Sugarcane Ethanol	0	0	0	0	0	0	0.050	0	0
Biogas from Cattle Dung	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	4.3E-04	0.011	4.3E-04
Charcoal from Wood	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04	8.4E-04
Biomass Pellets	0	0	0	0	0	0.029	0	0	0
Firewood	0.16	0.16	0.13	0.15	0.16	0.18	0.18	0.18	0.20
Crop Residue	0.044	0.044	0.035	0.040	0.044	0.049	0.049	0.049	0.055
Dung Cake	0.079	0.079	0.079	0.042	0.079	0.042	0.042	0.042	0.079
TOTAL	0.83	0.47	0.45	0.44	0.77	0.45	0.47	0.43	0.48

Table B-29. Detailed Results for Ozone Depletion by Baseline and Potential Scenarios in India

Ozone Depletion (kg CFC 11 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08
LPG from NG	1.2E-07	1.7E-07	2.2E-07	2.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07
LPG from Oil	3.9E-07	5.5E-07	7.0E-07	7.0E-07	3.9E-07	3.9E-07	3.9E-07	3.9E-07	3.9E-07
Kerosene	7.8E-08	7.8E-08	7.8E-08	7.8E-08	7.8E-08	7.8E-08	7.8E-08	7.8E-08	7.8E-08
Electricity	1.4E-07	5.6E-09	5.6E-09	5.6E-09	2.1E-07	5.6E-09	5.6E-09	5.6E-09	5.6E-09
Sugarcane Ethanol	0	0	0	0	0	0	6.3E-07	0	0
Biogas from Cattle Dung	0	0	0	0	0	0	0	0	0
Charcoal from Wood	1.8E-11	1.8E-11	1.8E-11	1.8E-11	1.8E-11	1.8E-11	1.8E-11	1.8E-11	1.8E-11
Biomass Pellets	0	0	0	0	0	3.2E-08	0	0	0
Firewood	1.0E-09	1.0E-09	8.2E-10	9.3E-10	1.0E-09	1.2E-09	1.2E-09	1.2E-09	1.3E-09
Crop Residue	2.2E-10	2.2E-10	1.7E-10	2.0E-10	2.2E-10	2.4E-10	2.4E-10	2.4E-10	2.7E-10
Dung Cake	6.6E-09	6.6E-09	6.6E-09	3.5E-09	6.6E-09	3.5E-09	3.5E-09	3.5E-09	6.6E-09
TOTAL	7.6E-07	8.2E-07	1.0E-06	1.0E-06	8.3E-07	6.5E-07	1.2E-06	6.2E-07	6.2E-07

Table B-30. Detailed Results for Black Carbon & Short-Lived Climate Pollutants by Baseline and Potential Scenarios in India

Black Carbon & Co emitted Species (kg BC eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Hard Coal	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
LPG from NG	2.9E-05	4.1E-05	5.3E-05	5.3E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05
LPG from Oil	0.0028	0.0039	0.0050	0.0050	0.0028	0.0028	0.0028	0.0028	0.0028
Kerosene	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
Electricity	-0.0020	-7.6E-05	-7.6E-05	-7.6E-05	-0.0020	-7.6E-05	-7.6E-05	-7.6E-05	-7.6E-05
Sugarcane Ethanol	0	0	0	0	0	0	-5.4E-04	0	0
Biogas from Cattle Dung	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	7.1E-04	2.7E-05
Charcoal from Wood	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Biomass Pellets	0	0	0	0	0	0.0020	0	0	0
Firewood	0.42	0.42	0.34	0.38	0.42	0.47	0.47	0.47	0.51
Crop Residue	0.17	0.17	0.14	0.16	0.17	0.19	0.19	0.19	0.22

Table B-30. Detailed Results for Black Carbon & Short-Lived Climate Pollutants by Baseline and Potential Scenarios in India

Black Carbon & Co emitted Species (kg BC eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase of Electrical Use in Urban**	**Increase of LPG in Urban**	**Increase in LPG/ Decrease in Biomass in both Urban and Rural**	**Increase in LPG/ Decrease in Biomass & Dung in Rural**	**Cleaner Electrical Grid with Increase in Urban**	**Increased Biomass Pellets/ Decreased Biomass & Dung**	**Increased Ethanol/ Decreased Biomass & Dung**	**Increased Biogas/ Decreased Biomass & Dung**	**Current Cookstove Fuel Use**
Dung Cake	0.53	0.53	0.53	0.28	0.53	0.28	0.28	0.28	0.53
TOTAL	1.22	1.23	1.10	0.91	1.22	1.04	1.04	1.04	1.35

Detailed LCA Results for China by Baseline and Potential Scenarios

This section offers the detailed results tables by baseline and potential scenarios of the selected LCI and LCIA categories for the individual cooking fuels used within China (Table B-31 through

Table B-40). Refer to Section 4.2, Results for China by Baseline and Potential Scenarios, of the report for discussion and a visual of each table in this section.

Table B-31. Detailed Results for Global Climate Change Potential by Baseline and Potential Scenarios in China

Global Climate Change Potential (kg CO_2 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	90.3	90.3	293	90.3	192	192	293	293	293
Coal Powder	57.4	57.4	186	57.4	122	122	93.1	186	186
Coal Briquettes	17.4	17.4	56.7	17.4	37.1	37.1	85.0	56.7	56.7
Honeycomb Coal Briquettes	15.5	15.5	50.2	15.5	32.8	32.8	75.3	50.2	50.2
Biomass Mix	48.0	48.0	12.0	48.0	30.0	30.0	48.0	29.7	48.0
Fuel & Brush Wood	41.4	41.4	10.4	41.4	25.9	25.9	41.4	18.8	41.4
Ag Residues	6.54	6.54	1.64	6.54	4.09	4.09	6.54	11.0	6.54
LPG	58.4	96.0	96.0	58.4	58.4	58.4	58.4	58.4	58.4
Kerosene	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Electricity	152	52.6	52.6	118	52.6	52.6	52.6	52.6	52.6
Natural Gas	5.12	5.12	5.12	5.12	5.12	5.12	5.12	5.12	5.12
Biomass Pellets	0	0	0	0	23.7	0	0	0	0
DME	0	0	0	0	0	69.1	0	0	0
TOTAL	**354**	**293**	**459**	**320**	**362**	**408**	**418**	**440**	**458**

Table B-32. Detailed Results for Cumulative Energy Demand by Baseline and Potential Scenarios in China

Cumulative Energy Demand (MJ)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	935	935	3,036	935	1,986	1,986	3,036	3,036	3,036
Coal Powder	568	568	1,844	568	1,206	1,206	922	1,844	1,844
Coal Briquettes	199	199	645	199	422	422	968	645	645
Honeycomb Coal Briquettes	168	168	546	168	357	357	820	546	546
Biomass Mix	1,909	1,909	479	1,909	1,194	1,194	1,909	2,019	1,909
Fuel & Brush Wood	964	964	242	964	603	603	964	436	964
Ag Residues	946	946	237	946	591	591	946	1,583	946
LPG	866	1,423	1,423	866	866	866	866	866	866
Kerosene	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
Electricity	1,854	642	642	1,510	642	642	642	642	642
Natural Gas	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2	49.2
Biomass Pellets	0	0	0	0	474	0	0	0	0
DME	0	0	0	0	0	1,279	0	0	0
TOTAL	**5,623**	**4,967**	**5,638**	**5,278**	**5,220**	**6,025**	**6,185**	**6,622**	**6,512**

Table B-33. Detailed Results for Fossil Depletion by Baseline and Potential Scenarios in China

Fossil Depletion (kg oil eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	16.0	16.0	51.8	16.0	33.9	33.9	51.8	51.8	51.8
Coal Powder	9.48	9.48	30.8	9.48	20.1	20.1	15.4	30.8	30.8
Coal Briquettes	3.51	3.51	11.4	3.51	7.46	7.46	17.1	11.4	11.4
Honeycomb Coal Briquettes	2.97	2.97	9.65	2.97	6.31	6.31	14.5	9.65	9.65
Biomass Mix	0.0022	0.0022	5.5E-04	0.0022	0.0014	0.0014	0.0022	0.0032	0.0022
Fuel & Brush Wood	3.6E-04	3.6E-04	9.1E-05	3.6E-04	2.3E-04	2.3E-04	3.6E-04	1.6E-04	3.6E-04
Ag Residues	0.0018	0.0018	4.6E-04	0.0018	0.0012	0.0012	0.0018	0.0031	0.0018
LPG	20.0	32.9	32.9	20.0	20.0	20.0	20.0	20.0	20.0
Kerosene	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Electricity	29.2	10.1	10.1	24.1	10.1	10.1	10.1	10.1	10.1
Natural Gas	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Biomass Pellets	0	0	0	0	1.62	0	0	0	0
DME	0	0	0	0	0	22.2	0	0	0
TOTAL	**66.6**	**60.4**	**96.2**	**61.5**	**67.1**	**87.6**	**78.5**	**83.4**	**83.4**

Table B-34. Detailed Results for Water Depletion by Baseline and Potential Scenarios in China

Water Depletion (m^3)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	3.96	3.96	12.9	3.96	8.42	8.42	12.9	12.9	12.9
Coal Powder	0.85	0.85	2.76	0.85	1.80	1.80	1.38	2.76	2.76
Coal Briquettes	1.70	1.70	5.51	1.70	3.61	3.61	8.27	5.51	5.51
Honeycomb Coal Briquettes	1.42	1.42	4.60	1.42	3.01	3.01	6.90	4.60	4.60
Biomass Mix	0.017	0.017	0.0042	0.017	0.011	0.011	0.017	0.025	0.017
Fuel & Brush Wood	0.0028	0.0028	7.0E-04	0.0028	0.0017	0.0017	0.0028	0.0013	0.0028
Ag Residues	0.014	0.014	0.0035	0.014	0.0088	0.0088	0.014	0.024	0.014
LPG	17.7	29.2	29.2	17.7	17.7	17.7	17.7	17.7	17.7
Kerosene	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Electricity	160	55.6	55.6	158	55.6	55.6	55.6	55.6	55.6
Natural Gas	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Biomass Pellets	0	0	0	0	9.84	0	0	0	0
DME	0	0	0	0	0	5.50	0	0	0
TOTAL	**183**	**89.1**	**98.0**	**180**	**92.0**	**87.6**	**90.3**	**86.6**	**86.6**

Table B-35. Detailed Results for Particulate Matter Formation by Baseline and Potential Scenarios in China

Particulate Matter Formation (kg PM10 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	0.16	0.16	0.52	0.16	0.34	0.34	0.52	0.52	0.52
Coal Powder	0.13	0.13	0.43	0.13	0.28	0.28	0.21	0.43	0.43
Coal Briquettes	0.015	0.015	0.049	0.015	0.032	0.032	0.074	0.049	0.049
Honeycomb Coal Briquettes	0.014	0.014	0.046	0.014	0.030	0.030	0.068	0.046	0.046
Biomass Mix	0.63	0.63	0.16	0.63	0.39	0.39	0.63	0.78	0.63
Fuel & Brush Wood	0.22	0.22	0.055	0.22	0.14	0.14	0.22	0.10	0.22
Ag Residues	0.41	0.41	0.10	0.41	0.25	0.25	0.41	0.68	0.41
LPG	0.062	0.10	0.10	0.062	0.062	0.062	0.062	0.062	0.062
Kerosene	7.0E-04	7.0E-04	7.0E-04	7.0E-04	7.0E-04	7.0E-04	7.0E-04	7.0E-04	7.0E-04
Electricity	0.41	0.14	0.14	0.31	0.14	0.14	0.14	0.14	0.14
Natural Gas	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014
Biomass Pellets	0	0	0	0	0.043	0	0	0	0
DME	0	0	0	0	0	0.15	0	0	0
TOTAL	**1.26**	**1.03**	**0.92**	**1.16**	**0.98**	**1.09**	**1.19**	**1.51**	**1.35**

Table B-36. Detailed Results for Photochemical Oxidant Formation by Baseline and Potential Scenarios in China

Photochemical Oxidant Formation (kg NMVOC eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	0.21	0.21	0.67	0.21	0.44	0.44	0.67	0.67	0.67
Coal Powder	0.15	0.15	0.48	0.15	0.31	0.31	0.24	0.48	0.48
Coal Briquettes	0.027	0.027	0.087	0.027	0.057	0.057	0.13	0.087	0.087
Honeycomb Coal Briquettes	0.033	0.033	0.11	0.033	0.071	0.071	0.16	0.11	0.11
Biomass Mix	0.57	0.57	0.14	0.57	0.35	0.35	0.57	0.62	0.57
Fuel & Brush Wood	0.27	0.27	0.067	0.27	0.17	0.17	0.27	0.12	0.27
Ag Residues	0.30	0.30	0.076	0.30	0.19	0.19	0.30	0.50	0.30
LPG	0.12	0.20	0.20	0.12	0.12	0.12	0.12	0.12	0.12
Kerosene	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013
Electricity	0.57	0.20	0.20	0.44	0.20	0.20	0.20	0.20	0.20
Natural Gas	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054
Biomass Pellets	0	0	0	0	0.052	0	0	0	0
DME	0	0	0	0	0	0.40	0	0	0
TOTAL	**1.48**	**1.18**	**1.23**	**1.35**	**1.18**	**1.53**	**1.43**	**1.63**	**1.57**

Table B-37. Detailed Results for Freshwater Eutrophication by Baseline and Potential Scenarios in China

Freshwater Eutrophication (kg P eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	0.0098	0.0098	0.032	0.0098	0.021	0.021	0.032	0.032	0.032
Coal Powder	0.0061	0.0061	0.020	0.0061	0.013	0.013	0.0099	0.020	0.020
Coal Briquettes	0.0020	0.0020	0.0065	0.0020	0.0042	0.0042	0.0097	0.0065	0.0065
Honeycomb Coal Briquettes	0.0017	0.0017	0.0055	0.0017	0.0036	0.0036	0.0082	0.0055	0.0055
Biomass Mix	0.054	0.054	0.014	0.054	0.034	0.034	0.054	0.080	0.054
Fuel & Brush Wood	0.0089	0.0089	0.0022	0.0089	0.0056	0.0056	0.0089	0.0040	0.0089
Ag Residues	0.045	0.045	0.011	0.045	0.028	0.028	0.045	0.076	0.045
LPG	0.0025	0.0041	0.0041	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Kerosene	3.1E-05	3.1E-05	3.1E-05	3.1E-05	3.1E-05	3.1E-05	3.1E-05	3.1E-05	3.1E-05
Electricity	0.019	0.0067	0.0067	0.014	0.0067	0.0067	0.0067	0.0067	0.0067
Natural Gas	1.6E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05
Biomass Pellets	0	0	0	0	0.0040	0	0	0	0
DME	0	0	0	0	0	0.013	0	0	0
TOTAL	**0.086**	**0.075**	**0.056**	**0.081**	**0.068**	**0.077**	**0.091**	**0.12**	**0.095**

Table B-38. Detailed Results for Terrestrial Acidification by Baseline and Potential Scenarios in China

Terrestrial Acidification (kg SO_2 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	0.33	0.33	1.08	0.33	0.70	0.70	1.08	1.08	1.08
Coal Powder	0.26	0.26	0.86	0.26	0.56	0.56	0.43	0.86	0.86
Coal Briquettes	0.036	0.036	0.12	0.036	0.076	0.076	0.17	0.12	0.12
Honeycomb Coal Briquettes	0.032	0.032	0.10	0.032	0.067	0.067	0.15	0.10	0.10
Biomass Mix	0.079	0.079	0.020	0.079	0.049	0.049	0.079	0.080	0.079
Fuel & Brush Wood	0.043	0.043	0.011	0.043	0.027	0.027	0.043	0.019	0.043
Ag Residues	0.036	0.036	0.0090	0.036	0.023	0.023	0.036	0.060	0.036
LPG	0.21	0.35	0.35	0.21	0.21	0.21	0.21	0.21	0.21
Kerosene	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
Electricity	1.31	0.45	0.45	0.99	0.45	0.45	0.45	0.45	0.45
Natural Gas	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041	0.0041
Biomass Pellets	0	0	0	0	0.078	0	0	0	0
DME	0	0	0	0	0	0.24	0	0	0
TOTAL	**1.94**	**1.22**	**1.90**	**1.61**	**1.50**	**1.66**	**1.51**	**1.83**	**1.83**

Table B-39. Detailed Results for Ozone Depletion by Baseline and Potential Scenarios in China

Ozone Depletion (kg CFC 11 eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	5.7E-07	5.7E-07	1.8E-06	5.7E-07	1.2E-06	1.2E-06	1.8E-06	1.8E-06	1.8E-06
Coal Powder	3.7E-08	3.7E-08	1.2E-07	3.7E-08	7.9E-08	7.9E-08	6.0E-08	1.2E-07	1.2E-07
Coal Briquettes	2.9E-07	2.9E-07	9.3E-07	2.9E-07	6.1E-07	6.1E-07	1.4E-06	9.3E-07	9.3E-07
Honeycomb Coal Briquettes	2.4E-07	2.4E-07	7.9E-07	2.4E-07	5.1E-07	5.1E-07	1.2E-06	7.9E-07	7.9E-07
Biomass Mix	8.9E-10	8.9E-10	2.2E-10	8.9E-10	5.5E-10	5.5E-10	8.9E-10	1.3E-09	8.9E-10
Fuel & Brush Wood	1.5E-10	1.5E-10	3.6E-11	1.5E-10	9.1E-11	9.1E-11	1.5E-10	6.6E-11	1.5E-10
Ag Residues	7.4E-10	7.4E-10	1.9E-10	7.4E-10	4.6E-10	4.6E-10	7.4E-10	1.2E-09	7.4E-10
LPG	9.2E-06	1.5E-05	1.5E-05	9.2E-06	9.2E-06	9.2E-06	9.2E-06	9.2E-06	9.2E-06
Kerosene	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
Electricity	7.0E-07	2.4E-07	2.4E-07	2.1E-06	2.4E-07	2.4E-07	2.4E-07	2.4E-07	2.4E-07
Natural Gas	8.2E-07	8.2E-07	8.2E-07	8.2E-07	8.2E-07	8.2E-07	8.2E-07	8.2E-07	8.2E-07
Biomass Pellets	0	0	0	0	4.7E-08	0	0	0	0
DME	0	0	0	0	0	4.5E-06	0	0	0
TOTAL	**1.1E-05**	**1.7E-05**	**1.8E-05**	**1.3E-05**	**1.2E-05**	**1.6E-05**	**1.3E-05**	**1.2E-05**	**1.2E-05**

Table B-40. Detailed Results for Black Carbon & Short-Lived Climate Pollutants by Baseline and Potential Scenarios in China

Black Carbon (kg BC eq)/GJ Heat Delivered for Cooking									
Fuels:	**Increase Electric**	**LPG Replaces Coal**	**LPG Replaces Biomass**	**Increase Clean Electric**	**Increase Biomass Pellets**	**Increase DME**	**Coal Swap**	**Ag Residue Replace Wood**	**Current**
Coal Mix	0.0039	0.0039	0.013	0.0039	0.0082	0.0082	0.013	0.013	0.013
Coal Powder	0.0018	0.0018	0.0060	0.0018	0.0039	0.0039	0.0030	0.0060	0.0060
Coal Briquettes	0.0010	0.0010	0.0034	0.0010	0.0022	0.0022	0.0050	0.0034	0.0034
Honeycomb Coal Briquettes	9.7E-04	9.7E-04	0.0032	9.7E-04	0.0021	0.0021	0.0047	0.0032	0.0032
Biomass Mix	0.13	0.13	0.032	0.13	0.079	0.079	0.13	0.13	0.13
Fuel & Brush Wood	0.044	0.044	0.011	0.044	0.027	0.027	0.044	0.020	0.044
Ag Residues	0.083	0.083	0.021	0.083	0.052	0.052	0.083	0.14	0.083
LPG	-0.0055	-0.0091	-0.0091	-0.0055	-0.0055	-0.0055	-0.0055	-0.0055	-0.0055
Kerosene	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05	-9.6E-05
Electricity	-0.037	-0.013	-0.013	-0.028	-0.013	-0.013	-0.013	-0.013	-0.013
Natural Gas	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05	-5.2E-05
Biomass Pellets	0	0	0	0	0.0021	0	0	0	0
DME	0	0	0	0	0	0.011	0	0	0
TOTAL	**0.088**	**0.11**	**0.022**	**0.097**	**0.071**	**0.080**	**0.12**	**0.15**	**0.12**