Comparative LCA of Cooking Fuel Options in India and China

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Introduction

- More than 2.6 billion people in India and China use traditional cookstove fuels
- Over 1 million premature deaths from cookstove air pollutants
- Rapid population growth increases demand for traditional fuels leading to environmental degradation

- US EPA in partnership with the Global Alliance for Clean Cookstoves is working to provide information to guide decisions in the cookstoves sector

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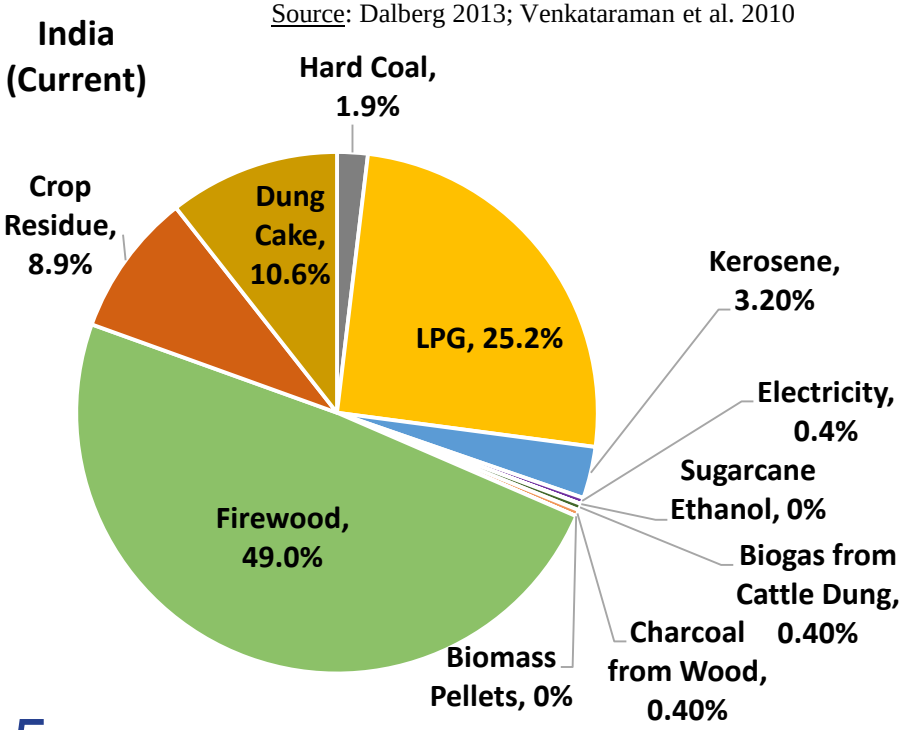
Introduction - Continued

- The term "clean cooking fuel" is commonly understood to represent fuels that produce less damaging emissions at the point of use
- Assessing only point of use emissions may neglect important impacts across the full life cycle of the fuel
- LCA conducted to facilitate a more holistic analysis of potential changes in cookstove fuel mixes to inform policy decisions and further sector knowledge

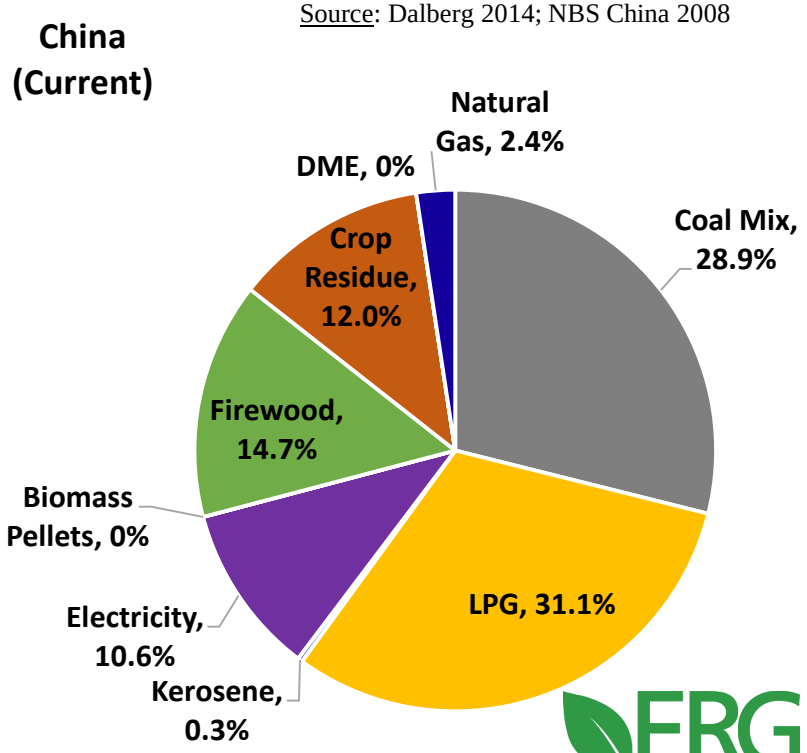
Goal and Scope

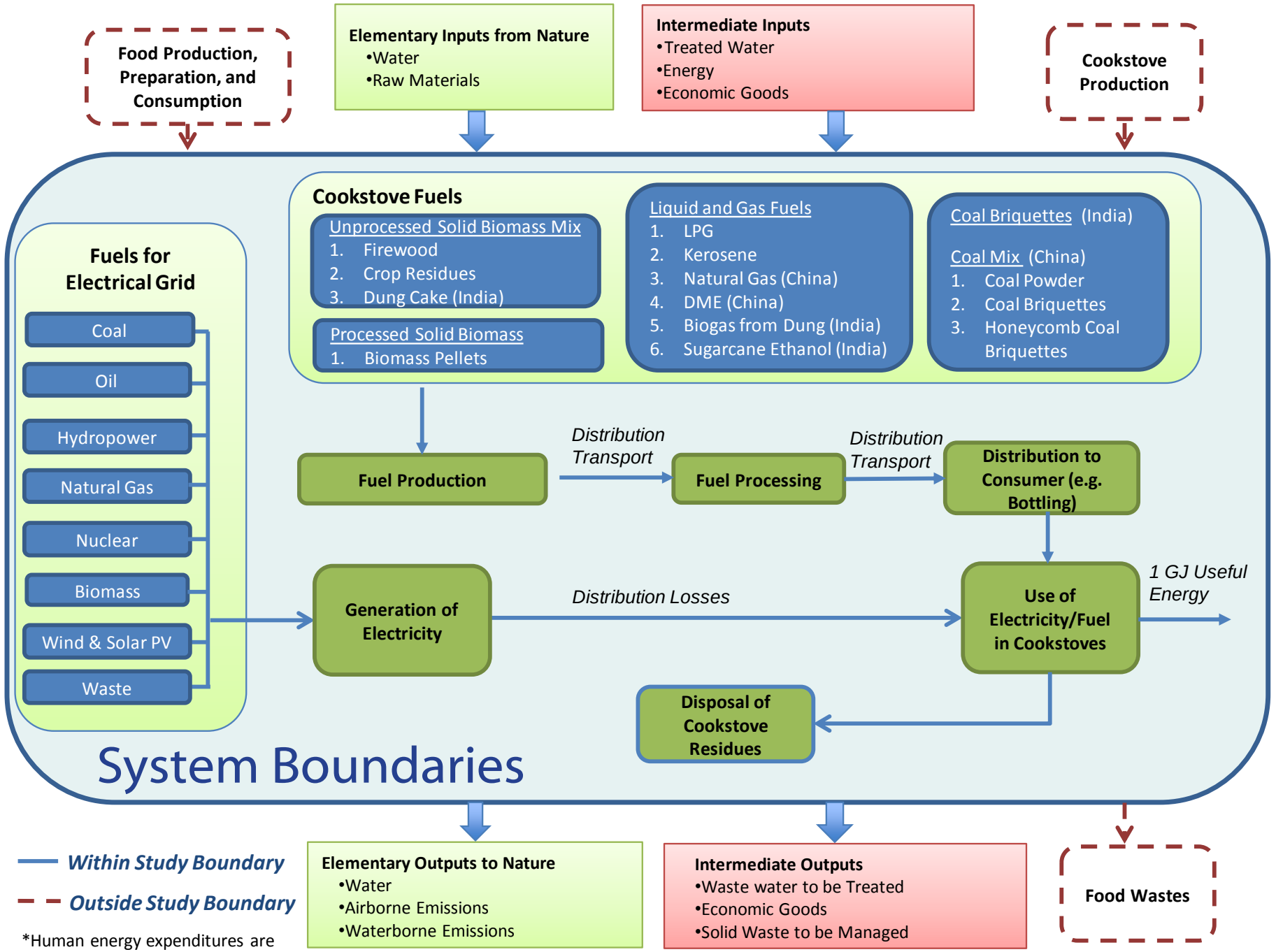
- Goal: Compare the environmental footprint of current and potential fuels and fuel mixes used for cooking within India and China
- Functional Unit: 1 GJ of useful energy delivered to the pot for cooking
- Fuel Systems Investigated:

Source: Dalberg 2013; Venkataraman et al. 2010



Source: Dalberg 2014; NBS China 2008




Food Production, Preparation, and Consumption
Elementary Inputs from Nature
•Water
•Raw Materials
Intermediate Inputs
•Treated Water
•Energy
•Economic Goods
Cookstove Production
Cookstove Fuels
Unprocessed Solid Biomass Mix
1. Firewood
2. Crop Residues
3. Dung Cake (India)
Processed Solid Biomass
1. Biomass Pellets
Liquid and Gas Fuels
1. LPG
2. Kerosene
3. Natural Gas (China)
4. DME (China)
5. Biogas from Dung (India)
6. Sugarcane Ethanol (India)
Coal Briquettes (India)
Coal Mix (China)
1. Coal Powder
2. Coal Briquettes
3. Honeycomb Coal Briquettes
Fuels for Electrical Grid
Coal
Oil
Hydropower
Natural Gas
Nuclear
Biomass
Wind & Solar PV
Waste
Fuel Production
Distribution Transport
Fuel Processing
Distribution Transport
Distribution to Consumer (e.g. Bottling)
Generation of Electricity
Distribution Losses
Use of Electricity/Fuel in Cookstoves
1 GJ Useful Energy
Disposal of Cookstove Residues
System Boundaries
Within Study Boundary
Outside Study Boundary
*Human energy expenditures are not included.
Elementary Outputs to Nature
•Water
•Airborne Emissions
•Waterborne Emissions
Intermediate Outputs
•Waste water to be Treated
•Economic Goods
•Solid Waste to be Managed
Food Wastes

Methodology

- Existing LCI data extracted from literature review of publicly available sources
- LCI data input into US Federal LCA Digital Commons Life Cycle Inventory Unit Process Templates and imported to OpenLCA
- Models created for each country and fuel combination
- LCIA results 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

Environmental Indicators Assessed

1. Global climate change potential (GCCP) (IPCC 2013)
2. Cumulative energy demand (CED)
3. Particulate matter (PM) formation (ReCiPe)
4. Black carbon (BC) and short-lived climate pollutants (GSF 2015)
5. Fossil fuel depletion (ReCiPe)
6. Photochemical oxidant formation (ReCiPe)
7. Water depletion (ReCiPe)
8. Terrestrial acidification potential
9. Freshwater eutrophication potential (ReCiPe)
10. Ozone depletion potential (ReCiPe)

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Fuel Mix Scenario Development

- Fuel profiles developed to assess the environmental impacts from the current fuel mix and projected fuel mix scenarios:
  - Increases in electricity used for cooking
  - Increases in electricity using a cleaner electricity grid
  - Increases of LPG use in urban and/or rural areas, and
  - Increases of other cleaner burning fuels (e.g., biomass pellets, DME, ethanol, and biogas) currently used in smaller amounts

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	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%
LPG from Natural Gas (NG)	5.3%	5.3%	7.4%	9.5%	5.3%	9.5%	5.3%	5.3%	5.3%
LPG from Crude Oil (CO)	19.9%	19.9%	27.8%	35.7%	19.9%	35.7%	19.9%	19.9%	19.9%
Kerosene	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%	3.2%
Electricity	0.4%	10.4%	0.4%	0.4%	10.4%	0.4%	0.4%	0.4%	0.4%
Sugarcane Ethanol	0%	0%	0%	0%	0%	0%	0%	10.0%	0%
Biogas from Cattle Dung	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	10.4%
Charcoal from Wood	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Biomass Pellets	0%	0%	0%	0%	0%	0%	10.0%	0%	0%
Firewood	49.0%	40.7%	40.7%	32.2%	40.7%	36.5%	45.0%	45.0%	45.0%
Crop Residue	8.9%	7.2%	7.2%	5.7%	7.2%	6.4%	7.9%	7.9%	7.9%
Dung Cake	10.6%	10.6%	10.6%	10.6%	10.6%	5.6%	5.6%	5.6%	5.6%

Color Coding Legend:

indicates decrease from current scenario

indicates increase from current scenario

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Cooking Fuel Mix Scenarios Evaluated for China

Fuels		Current	Increase Electric	LPG replaces Coal	LPG replaces Biomass	Increase Clean Electric	Increase Biomass Pellets	Increase DME	Coal Swap	Ag replaces Wood
		Scenario	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coal Mix		28.9%	8.9%	8.9%	28.9%	8.9%	18.9%	18.9%	28.9%	28.9%
50%	Coal Powder	14.5%	4.5%	4.5%	14.5%	4.5%	9.5%	9.5%	7.2%	14.5%
25%	Coal Briquettes	7.2%	2.2%	2.2%	7.2%	2.2%	4.7%	4.7%	10.8%	7.2%
25%	Honeycomb Coal Briquettes	7.2%	2.2%	2.2%	7.2%	2.2%	4.7%	4.7%	10.8%	7.2%
Biomass Mix		26.7%	26.7%	26.7%	6.7%	26.7%	16.7%	16.7%	26.7%	26.7%
55%	Fuel & Brush Wood	14.7%	14.7%	14.7%	3.7%	14.7%	9.2%	9.2%	14.7%	6.7%
45%	Ag Residues	12.0%	12.0%	12.0%	3.0%	12.0%	7.5%	7.5%	12.0%	20.0%
LPG		31.1%	31.1%	51.1%	51.1%	31.1%	31.1%	31.1%	31.1%	31.1%
Kerosene		0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Electricity		10.6%	30.6%	10.6%	10.6%	30.6%	10.6%	10.6%	10.6%	10.6%
Natural Gas		2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
Biomass Pellets		0%	0%	0%	0%	0%	20.0%	0%	0%	0%
DME		0%	0%	0%	0%	0%	0%	20.0%	0%	0%

Color Coding Legend:

indicates decrease from current scenario

indicates increase from current scenario

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Stove Efficiencies

Chinese Stove Efficiencies

Fuels:	Stove Thermal Efficiencies	Improved
Coal Mix	22%	23%
Coal Powder	14%	17%
Coal Briquettes	37%	27%
Honeycomb Coal Briquettes	23%	31%
Biomass Mix	15%	17%
Fuel & Brush Wood	19%	16%
Ag Residues	10%	17%
LPG	45%	42%
Kerosene	45%	46%
Electricity	67%	
Natural Gas	54%	61%
Biomass Pellets	53%	
DME	46%	

Indian Stove Efficiencies

Fuels	Stove Thermal Efficiency
Hard Coal	16%
LPG from NG	57%
LPG from CO	57%
Kerosene	47%
Electricity	67%
Sugarcane Ethanol	53%
Biogas from Cattle Dung	55%
Charcoal from Wood	18%
Biomass Pellets	53%
Firewood	14%
Crop Residue	11%
Dung Cake	9%

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Results

- Modeling and analysis complete
- The LCA model built can serve as the basis to further the understanding of quantifiable and holistic tradeoffs between cookstove fuel choices
- Help decision-makers spur initiatives to shift to "cleaner" fuel choices
- Draft report submitted for EPA QA and Peer Review

Next Steps

- Finalize report
- Report will be publicly available
- Framework constructed can be continually improved in next research steps in coordination with the Global Alliance for Clean Cookstoves:
  - Additional sensitivity analyses
  - Uncertainty analysis
  - Increased geographic coverage
  - Improved data as more sources become available

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Thank you

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