SUPPORTING APPENDIX FOR

Direct energy consumption associated emissions by rural-to-urban migrants in Beijing
Ru MY1, Tao S1*, Smith KR2, Shen GF1, Shen HZ1, Huang Y1, Chen H1, Chen YL1, Chen Xi1, Liu JF1, Li BG1, Wang XL1, He CF1

1. Laboratory for Earth Surface Processes, College of Urban and Environmental Sciences, Peking University, Beijing 100871, P.R. China
2. UC Berkeley, California, 94720-1234, USA

Number of pages: 12
Number of tables: 5
Number of figures: 6
Survey on Residential Energy Consumption for Migrants in Beijing

Does your Hukou (registration place) locate in Beijing?
A. Yes  
B. No  

Address of Homeplace
Province: ____________
City: ____________
Country: ____________
Town or village: ____________

Gender
A. male  
B. female  

Housing status?
A. self-owned  
B. rented  

Monthly rent (if applicable)
_________ yuan

Current address in Beijing


How many roommates or family members are you living together with?


Your housing type
A. bungalow  
B. multistoried apartment without elevator  
C. multistoried apartment with elevator  
D. basement  
E. houses built privately on farmers’ land  
F. temporary shed

How long has it been since you reside in Beijing?
_________ Years and ________ months

Average monthly income
_________ yuan

Your way of daily commuting
A. public transportation  
B. bicycle  
C. private car  
   daily gasoline spending: ________ yuan  
D. electric bicycle

What home appliances do you have (choose all you have)?
A. electric heater  
B. television  
C. air conditioner  
D. deductive stove  
E. washing machine  
F. electric rice cooker  
G. refrigerator  
H. computer  
I. electric water heater  
J. electric fan  
K. microwave oven  
L. electric bicycle  
M. water kettle

Monthly spending on household electricity
A. 0 - 50 yuan  
B. 50 - 70 yuan  
C. 70 - 90 yuan  
D. 90 - 100 yuan  
E. 100 - 150 yuan  
F. 150 - 200 yuan  
G. > 200 yuan

Do you use gas powered water heater on household?
Household total use per day: ________ minutes

What cooking energy do you use (you can choose more than one)
A. pipeline natural gas  
B. liquid propane gas  
C. honeycomb coal briquette  
D. chunk coal  
E. firewood  
F. electricity  
G. others, please specify: ____________

Monthly spending on cooking per person
A. 0 - 10 yuan  
B. 10 - 20 yuan  
C. 20 - 30 yuan  
D. 30 - 40 yuan  
E. > 40 yuan

What do you use for heating in winter (choose all that applies)?
A. no heating  
B. centralized heating system  
C. build-in electricity heater  
D. electric heater  
E. honeycomb coal briquette stove  
F. chunk coal stove  
G. firewood  
H. others, please specify: ____________

Yearly spending on heating per person:
A. 0 - 200 yuan  
B. 200 - 400 yuan  
C. 400 - 600 yuan  
D. 600 - 800 yuan  
E. 800 - 1000 yuan  
F. 1000 - 1500 yuan  
G. 1500 - 2000 yuan  
G. > 2000 yuan

Monthly spending on water per person:
A. 0 - 10 yuan  
B. 10 - 20 yuan  
C. 20 - 30 yuan  
D. 30 - 40 yuan  
E. 40 - 50 yuan  
F. 50 - 80 yuan

(All currency used in this questionnaire are in RMB)

----- This is the end of the survey. Thank you!

Figure S1 Design of the questionnaire
Figure S2 Flow chart of the 2-stage survey methods.

In the community stage, 440 of the retrieved questionnaires were finally used for data analysis. The left 370 were either not well filled or appeared not to be treated seriously. The reason might lie in the fact that school children were the intersection between us and the true respondents - parents or other family members who were migrant labors. Children might have failed to deliver the questionnaires to their parents.
### Table S1a Calculating price-to-energy factors for converting residential fuel prices to mass/volume, and to megajoules

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Prices(^1)</th>
<th>Standardized coefficients for mass/volume units (^2)</th>
<th>Converting mass/volume(\text{Price-to-energy conversion factors})(^3)</th>
<th>Converting(\text{Price-to-energy conversion factors})(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal central heating</td>
<td>20 yuan/m(^2)</td>
<td>0.0251 tce/m(^2)</td>
<td>29271 MJ/tce</td>
<td>0.027</td>
</tr>
<tr>
<td>PNG</td>
<td>2.28 yuan/m(^3)</td>
<td></td>
<td>38.93 MJ/m(^3)</td>
<td>0.059</td>
</tr>
<tr>
<td>LPG</td>
<td>105 yuan/canister</td>
<td>15 kg/canister</td>
<td>50.179 MJ/kg</td>
<td>0.140</td>
</tr>
<tr>
<td>Coal</td>
<td>1.2 yuan/piece</td>
<td>1.25 kg/piece</td>
<td>17.563 MJ/kg</td>
<td>0.055</td>
</tr>
<tr>
<td>Coal lump coal/chunk coal</td>
<td>0.75 yuan/kg</td>
<td>20.908 MJ/kg</td>
<td>0.036</td>
<td></td>
</tr>
<tr>
<td>Crop rural residues</td>
<td>free NA</td>
<td>14.50 MJ/kg</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Wood rural area of Beijing</td>
<td>6 yuan/kg</td>
<td>16.726 MJ/kg</td>
<td>0.359</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table S1-b Calculating weighted average of converting factors from electricity price to megajoules for coal, oil, and natural gas fired power plants

<table>
<thead>
<tr>
<th>Source of energy</th>
<th>Electricity price(\text{yuan/kWh})</th>
<th>Efficiency(^4)</th>
<th>Conversion factor(^5)</th>
<th>Power station mix(^6)</th>
<th>Weighted average of conversion(\text{MJ/kWh})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.4883</td>
<td>0.333</td>
<td>3.596</td>
<td>0.762</td>
<td>2.830</td>
</tr>
<tr>
<td>Oil</td>
<td>0.336</td>
<td></td>
<td>3.628</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Natural Gas-f</td>
<td>0.439</td>
<td></td>
<td>4.741</td>
<td>0.015</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

\(^1\) Prices are unit prices in residential sector in 2010 in Beijing.

\(^2\) Standardized units coefficient are the unit conversion from unit for charging prices to standardized mass or volume unit for energy calculation.

\(^3\) Conversion factors are coefficients that transform mass or volume units to energy unit of Mega joule. All conversion factors are Lower Heating Values (LHV).

\(^4\) Price to energy conversion is the Quotient of price and standardized units coefficient and conversion factors. Its unit is yuan/MJ, which can be used to transform expenditures directly to MJ.

\(^5\) For electricity, efficiency is output divided by input. It shows the demand for raw fossil fuels to produce 1 kWh of electricity. Note that transmission loss is not included, as with all other fuels listed here are only considered for end use.

\(^6\) Conversion factor is the energy needed in input fuels to provide 1 kilowatt hour of electricity. Efficiencies for different types of power plants matter as they have different capabilities to transform energy in fuels to electricity. Because the absence of direct data source, conversion factors for oil-fired and natural gas-fired power plants are calculated using coal-fired conversion factor and the efficiencies. e.g. \(\text{CF}_{\text{oil-fired}} = \text{CF}_{\text{coalfired}} \times \eta_{\text{oil-fired}} / \eta_{\text{coalfired}}\), where CF is conversion factor, and \(\eta\) is efficiency.

\(^7\) Power station mix shows the percentage of power produced by a type of power plant out of total power produced by all kinds of power plants. Note that the total is less than 100% because generation from nuclear and renewables are considered as emission free and is not included in this paper.

\(^8\) Weighted average of the coal, gas, and oil fired power plants represents the fuel consumption in power sector, and is used for all energy calculation and emission estimation in this paper. It correspond to all end-use consumption, including all kinds of energy losses within the power station, but excluding losses in power transmission.

References

Table S2  Emission factors of various air pollutants

<table>
<thead>
<tr>
<th>Energy</th>
<th>CO₂</th>
<th>SO₂</th>
<th>PM₁₀</th>
<th>PM₂.₅</th>
<th>EC</th>
<th>OC</th>
<th>CO</th>
<th>NOₓ</th>
<th>Hg</th>
<th>PAHs</th>
<th>BaP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tC/GJ</td>
<td>g/GJ</td>
<td>g/GJ</td>
<td>g/GJ</td>
<td>g/GJ</td>
<td>g/GJ</td>
<td>g/GJ</td>
<td>mg/GJ</td>
<td>mg/GJ</td>
<td>mg/GJ</td>
<td>mg/GJ</td>
</tr>
<tr>
<td>Elec. coal</td>
<td>24300</td>
<td>744</td>
<td>98.1</td>
<td>49.0</td>
<td>0.452</td>
<td>0.512</td>
<td>57.9</td>
<td>237</td>
<td>8.11</td>
<td>1.63</td>
<td>0.091</td>
</tr>
<tr>
<td>Elec. oil</td>
<td>20200</td>
<td>221</td>
<td>8.76</td>
<td>6.64</td>
<td>0.319</td>
<td>0.553</td>
<td>29.5</td>
<td>216</td>
<td>0.343</td>
<td>15.8</td>
<td>0.060</td>
</tr>
<tr>
<td>Elec. gas</td>
<td>13800</td>
<td>7.19</td>
<td>2.99</td>
<td>2.99</td>
<td>0.005</td>
<td>0.037</td>
<td>49.1</td>
<td>102</td>
<td>1.23</td>
<td>0.068</td>
<td>0.001</td>
</tr>
<tr>
<td>Thermal</td>
<td>24300</td>
<td>397</td>
<td>98.1</td>
<td>49.0</td>
<td>0.452</td>
<td>0.512</td>
<td>57.9</td>
<td>190</td>
<td>8.11</td>
<td>1.63</td>
<td>0.091</td>
</tr>
<tr>
<td>Gasoline</td>
<td>18200</td>
<td>56.2</td>
<td>75.4</td>
<td>68.9</td>
<td>5.09</td>
<td>9.84</td>
<td>2870</td>
<td>337</td>
<td>0.078</td>
<td>4390</td>
<td>7.73</td>
</tr>
<tr>
<td>PNG</td>
<td>13800</td>
<td>7.45</td>
<td>2.81</td>
<td>2.81</td>
<td>0.308</td>
<td>0.038</td>
<td>20.6</td>
<td>54.4</td>
<td>0.0056</td>
<td>2.70</td>
<td>0.037</td>
</tr>
<tr>
<td>LPG</td>
<td>16300</td>
<td>1.20</td>
<td>10.4</td>
<td>10.4</td>
<td>1.11</td>
<td>1.04</td>
<td>192</td>
<td>28.1</td>
<td>0.173</td>
<td>8.67</td>
<td>0.070</td>
</tr>
<tr>
<td>Coal</td>
<td>24300</td>
<td>500</td>
<td>478</td>
<td>375</td>
<td>174</td>
<td>227</td>
<td>5010</td>
<td>66.0</td>
<td>16.5</td>
<td>7890</td>
<td>81.0</td>
</tr>
<tr>
<td>Crop residues</td>
<td>0</td>
<td>27.3</td>
<td>413</td>
<td>400</td>
<td>53.9</td>
<td>135</td>
<td>6340</td>
<td>97.0</td>
<td>1.04</td>
<td>4540</td>
<td>65.4</td>
</tr>
<tr>
<td>Wood</td>
<td>0</td>
<td>21.0</td>
<td>325</td>
<td>274</td>
<td>102</td>
<td>179</td>
<td>4760</td>
<td>73.3</td>
<td>1.21</td>
<td>15700</td>
<td>92.8</td>
</tr>
</tbody>
</table>

References:


S5


100. UNEP Chemicals Branch (2011) Toolkit for identification and quantification of mercury releases, Revised Inventory Level 2 Report, Geneva, Switzerland.
Table S3 Fraction of non-renewable traditional woodfuels for Chinese provinces

<table>
<thead>
<tr>
<th>Province</th>
<th>Expected fraction of non-renewable biomass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anhui</td>
<td>26.3</td>
</tr>
<tr>
<td>Beijing</td>
<td>44.7</td>
</tr>
<tr>
<td>Chongqing</td>
<td>22.6</td>
</tr>
<tr>
<td>Fujian</td>
<td>4.9</td>
</tr>
<tr>
<td>Gansu</td>
<td>13.1</td>
</tr>
<tr>
<td>Guangdong</td>
<td>0.0</td>
</tr>
<tr>
<td>Guangxi</td>
<td>22.8</td>
</tr>
<tr>
<td>Guizhou</td>
<td>23.1</td>
</tr>
<tr>
<td>Hainan</td>
<td>8.8</td>
</tr>
<tr>
<td>Hebei</td>
<td>18.4</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>9.3</td>
</tr>
<tr>
<td>Henan</td>
<td>22.2</td>
</tr>
<tr>
<td>Hubei</td>
<td>29.0</td>
</tr>
<tr>
<td>Hunan</td>
<td>35.4</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>12.8</td>
</tr>
<tr>
<td>Jiangxi</td>
<td>24.9</td>
</tr>
<tr>
<td>Jilin</td>
<td>9.0</td>
</tr>
<tr>
<td>Liaoning</td>
<td>9.0</td>
</tr>
<tr>
<td>Inner Mongolia</td>
<td>10.1</td>
</tr>
<tr>
<td>Ningxia</td>
<td>9.0</td>
</tr>
<tr>
<td>Qinghai</td>
<td>10.0</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>34.8</td>
</tr>
<tr>
<td>Shandong</td>
<td>11.9</td>
</tr>
<tr>
<td>Shanghai</td>
<td>8.8</td>
</tr>
<tr>
<td>Shanxi</td>
<td>31.1</td>
</tr>
<tr>
<td>Sichuan</td>
<td>23.9</td>
</tr>
<tr>
<td>Taiwan</td>
<td>9.3</td>
</tr>
<tr>
<td>Tianjin</td>
<td>19.6</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>10.0</td>
</tr>
<tr>
<td>Xizang</td>
<td>14.2</td>
</tr>
<tr>
<td>Yunnan</td>
<td>14.5</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>21.1</td>
</tr>
</tbody>
</table>

Notes:
In the cited paper, we chose the scenario under low plantation productivity. And the data are the expected values of non-renewable biomass with consideration for biomass available from deforestation and afforestation.

References:
### Table S4 Standard deviations of emission factors for Monte Carlo simulation

<table>
<thead>
<tr>
<th>Energy</th>
<th>CO$_2$</th>
<th>SO$_2$</th>
<th>PM$_{10}$</th>
<th>PM$_{2.5}$</th>
<th>EC</th>
<th>OC</th>
<th>CO</th>
<th>Hg</th>
<th>PAHs</th>
<th>BaP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tC/GJ</td>
<td>lg(g/GJ)</td>
<td>lg(g/GJ)</td>
<td>lg(g/GJ)</td>
<td>lg(g/GJ)</td>
<td>lg(g/GJ)</td>
<td>lg(g/GJ)</td>
<td>lg(mg/GJ)</td>
<td>lg(mg/GJ)</td>
<td>lg(mg/GJ)</td>
</tr>
<tr>
<td>Elec. coal</td>
<td>890</td>
<td>0.78</td>
<td>0.15</td>
<td>0.15</td>
<td>0.55</td>
<td>0.46</td>
<td>0.38</td>
<td>0.21</td>
<td>0.24</td>
<td>0.52</td>
</tr>
<tr>
<td>Elec. oil</td>
<td>750</td>
<td>0.39</td>
<td>0.38</td>
<td>0.38</td>
<td>0.31</td>
<td>1.12</td>
<td>0.50</td>
<td>0.20</td>
<td>0.24</td>
<td>0.92</td>
</tr>
<tr>
<td>Elec. gas</td>
<td>60</td>
<td>0.63</td>
<td>0.16</td>
<td>0.16</td>
<td>0.50</td>
<td>0.50</td>
<td>0.24</td>
<td>0.16</td>
<td>0.50</td>
<td>3.36</td>
</tr>
<tr>
<td>Thermal</td>
<td>890</td>
<td>0.78</td>
<td>0.15</td>
<td>0.15</td>
<td>0.55</td>
<td>0.46</td>
<td>0.38</td>
<td>0.13</td>
<td>0.24</td>
<td>0.52</td>
</tr>
<tr>
<td>Gasoline</td>
<td>910</td>
<td>0.52</td>
<td>0.79</td>
<td>0.79</td>
<td>0.21</td>
<td>0.58</td>
<td>0.58</td>
<td>0.26</td>
<td>0.06</td>
<td>0.13</td>
</tr>
<tr>
<td>PNG</td>
<td>60</td>
<td>0.63</td>
<td>0.16</td>
<td>0.16</td>
<td>0.50</td>
<td>0.50</td>
<td>0.23</td>
<td>0.35</td>
<td>0.28</td>
<td>3.36</td>
</tr>
<tr>
<td>LPG</td>
<td>180</td>
<td>0.69</td>
<td>0.55</td>
<td>0.55</td>
<td>0.50</td>
<td>0.15</td>
<td>0.61</td>
<td>0.82</td>
<td>0.25</td>
<td>0.34</td>
</tr>
<tr>
<td>Coal</td>
<td>890</td>
<td>0.79</td>
<td>0.45</td>
<td>0.45</td>
<td>0.35</td>
<td>0.70</td>
<td>0.20</td>
<td>0.49</td>
<td>0.35</td>
<td>0.47</td>
</tr>
<tr>
<td>Crop residues</td>
<td>900</td>
<td>0.67</td>
<td>0.27</td>
<td>0.27</td>
<td>0.18</td>
<td>0.27</td>
<td>0.23</td>
<td>0.29</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>Wood</td>
<td>900</td>
<td>0.78</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.41</td>
<td>0.40</td>
<td>0.23</td>
<td>0.12</td>
<td>0.30</td>
</tr>
</tbody>
</table>

**Notes:**
For emission activities, coefficients of variance were assumed to be 5% for power and thermal stations, 10% for gasoline, PNG, LPG, and coal, and 20% for biomass fuels.

The standard deviations listed in the table are log-transformed except for CO$_2$.

### Table S5 Per person residential energy consumptions (GJ) for the RRs, MIs, and URs

<table>
<thead>
<tr>
<th>Usage</th>
<th>Energy</th>
<th>URs</th>
<th>MIs</th>
<th>RRs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household</td>
<td>Electricity</td>
<td>3.15</td>
<td>2.79</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Thermal</td>
<td>2.62</td>
<td>1.13</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>PNG</td>
<td>3.54</td>
<td>0.67</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>LPG</td>
<td>0.68</td>
<td>1.27</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Coal</td>
<td>1.39</td>
<td>5.84</td>
<td>1.99</td>
</tr>
<tr>
<td></td>
<td>Crop residues</td>
<td>0.00</td>
<td>0.00</td>
<td>10.77</td>
</tr>
<tr>
<td></td>
<td>Wood</td>
<td>0.00</td>
<td>0.12</td>
<td>4.60</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td><strong>11.39</strong></td>
<td><strong>11.82</strong></td>
<td><strong>18.48</strong></td>
</tr>
</tbody>
</table>

**References**

**Figure S4** Origins of the rural-to-urban migrants investigated in this study in comparison with distribution of rural-to-urban migrants in China. The two distributions are similar with top five provinces of Henan, Hebei, Anhui, Shandong, and Sichuan.
**Figure S3** Current addresses of the rural-to-urban migrants investigated in this study.
Figure S5 Relationship between number of home appliances and family size (two blank circles were outliers with relatively small sample sizes) (A) and between the number of home appliance and the length of the MIs have stayed in the city (B).

Figure S6 Per person annual emissions of CO₂, SO₂, Hg, BC, OC, PM₂.₅, PM₁₀, PAHs, BaP, CO, and NOx from residential energy consumption of the URs, MIs, and RRs. Emissions from various sources are shown as stacked bars. The blue lines are standard deviations calculated from Monte Carlo simulation indicating uncertain ranges (difference between the first and the third quartiles) of individual sources.