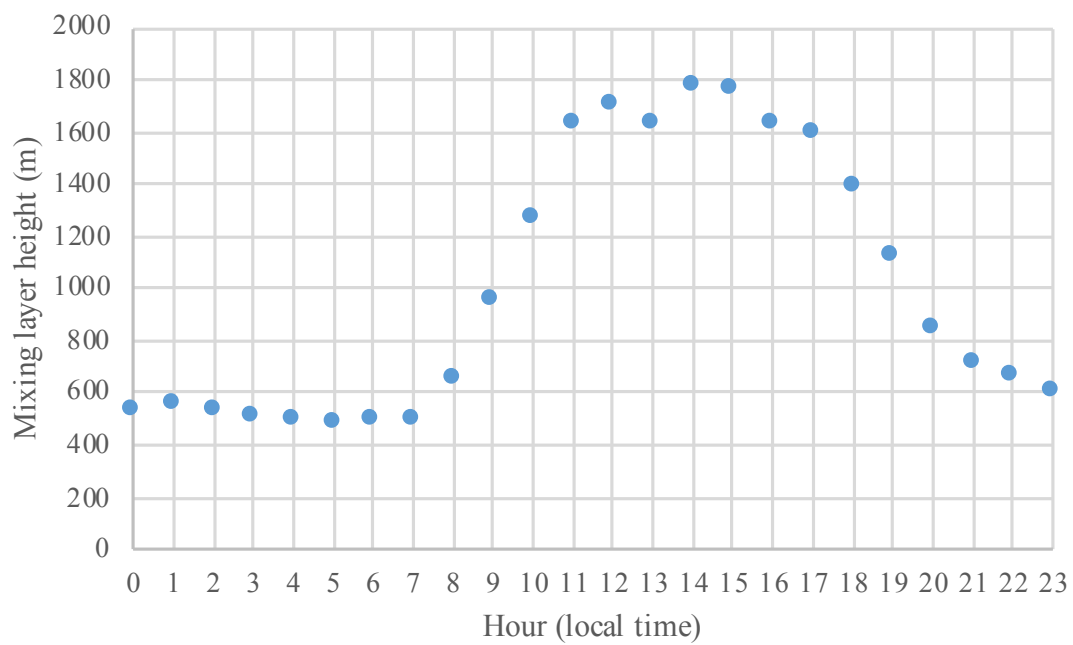


**Figure S1.** Simulated daily AOD, surface PM<sub>2.5</sub> and CO in April 12-14, 2015. Kathmandu Valley is indicated with an open star in the figure.



**Figure S2.** Averaged diurnal cycle of the mixing layer height (m) as simulated by WRF-Chem (HTAP\_vehicle\_brick) for the period April 12-24, 2015.

**Table S1a.** Vehicle technology used as IVE model inputs in 2015

Motorcycle									
Description	Fuel	Weight	Air/Fuel Control	Exhaust Control	Evaporative Control	Age	Index	Share	Corresponding Euro Standards
Small Engine	Petrol	Light	4-Cycle, Carb	None	None	>50K	1208	0.010	Pre-Euro
Small Engine	Petrol	Light	4-Cycle, Carb	Improved	None	26-50K	1216	0.010	Pre-Euro
Small Engine	Petrol	Light	4-Cycle, Carb	Improved	None	>50K	1217	0.040	Pre-Euro
Small Engine	Petrol	Medium	4-Cycle, Carb	Improved	None	26-50K	1219	0.010	Pre-Euro
Small Engine	Petrol	Medium	4-Cycle, Carb	Improved	None	>50K	1220	0.020	Pre-Euro
Small Engine	Petrol	Light	4-Cycle, Carb	High Tech	None	0-25K	1224	0.010	Euro III
Small Engine	Petrol	Light	4-Cycle, Carb	High Tech	None	26-50K	1225	0.040	Pre-Euro
Small Engine	Petrol	Light	4-Cycle, Carb	High Tech	None	>50K	1226	0.020	Pre-Euro
Small Engine	Petrol	Medium	4-Cycle, Carb	High Tech	None	0-25K	1227	0.030	Euro III
Small Engine	Petrol	Medium	4-Cycle, Carb	High Tech	None	26-50K	1228	0.030	Euro III
Small Engine	Petrol	Medium	4-Cycle, Carb	High Tech	None	>50K	1229	0.040	Pre-Euro
Small Engine	Petrol	Light	4-Cycle, Carb	Catalyst	None	0-25K	1233	0.020	Euro III
Small Engine	Petrol	Light	4-Cycle, Carb	Catalyst	None	26-50K	1234	0.030	Euro III
Small Engine	Petrol	Light	4-Cycle, Carb	Catalyst	None	>50K	1235	0.010	Pre-Euro
Small Engine	Petrol	Medium	4-Cycle, Carb	Catalyst	None	0-25K	1236	0.450	Euro III
Small Engine	Petrol	Medium	4-Cycle, Carb	Catalyst	None	26-50K	1237	0.110	Euro III
Small Engine	Petrol	Medium	4-Cycle, Carb	Catalyst	None	>50K	1238	0.040	Pre-Euro
Small Engine	Petrol	Medium	4-Cycle, FI	Catalyst	PCV	0-25K	1245	0.070	Euro III
Small Engine	Petrol	Medium	4-Cycle, FI	Catalyst	PCV	26-50K	1246	0.010	Pre-Euro

Bus/Mini bus									
Truck/Bus	Diesel	Heavy	Pre-Chamber Injection	None	None	>161K km	1079	0.100	Pre-Euro
Truck/Bus	Diesel	Heavy	Direct Injection	EGR+Improved	None	80-161K km	1096	0.010	Pre-Euro
Truck/Bus	Diesel	Heavy	Direct Injection	EGR+Improved	None	>161K km	1097	0.010	Pre-Euro
Truck/Bus	Diesel	Heavy	FI	Particulate/NOx	None	80-161K km	1114	0.010	Pre-Euro
Truck/Bus	Diesel	Heavy	FI	Particulate/NOx	None	>161K km 1115	0.050	Pre-Euro	
Truck/Bus	Diesel	Heavy	FI	EuroI	None	<79K km	1122	0.010	Euro I
Truck/Bus	Diesel	Heavy	FI	EuroI	None	80-161K km	1123	0.020	Euro I
Truck/Bus	Diesel	Heavy	FI	EuroI	None	>161K km	1124	0.190	Euro I
Truck/Bus	Diesel	Heavy	FI	EuroII	None	<79K km	1131	0.320	Euro II
Truck/Bus	Diesel	Heavy	FI	EuroII	None	80-161K km	1132	0.100	Euro II
Truck/Bus	Diesel	Heavy	FI	EuroII	None	>161K km	1133	0.180	Euro II

Taxi									
Auto/Small Truck	Petrol	Light	Multi-Pt FI	none	PCV	80-161K km	100	0.03	Pre-Euro
Auto/Small Truck	Petrol	Light	Multi-Pt FI	none	PCV	>161K km	101	0.28	Pre-Euro
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroI	PCV/Tank	<79K km	171	0.04	Euro I
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroI	PCV/Tank	80-161K km	172	0.11	Euro I
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroI	PCV/Tank	>161K km	173	0.45	Euro I
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroII	PCV/Tank	<79K km	180	0.04	Euro II
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroII	PCV/Tank	80-161K km	181	0.02	Euro II
Auto/Small Truck	Petrol	Light	Multi-Pt FI	EuroII	PCV/Tank	>161K km	182	0.03	Euro II

**Table S1b.** Vehicle technology used as IVE model inputs in 2015

Car/Pickup									
Auto/Small Truck	Petrol	Medium	Carburetor	2-Way	PCV	<79K km	12	0.004	Euro I
Auto/Small Truck	Petrol	Light	Carburetor	3-Way	PCV	<79K km	27	0.006	Euro I
Auto/Small Truck	Petrol	Medium	Carburetor	3-Way	PCV	<79K km	30	0.003	Euro I
Auto/Small Truck	Petrol	Light	Single-Pt FI	2-Way	PCV	<79K km	63	0.325	Euro I
Auto/Small Truck	Petrol	Light	Single-Pt FI	2-Way	PCV	80-161K km	64	0.013	Euro I
Auto/Small Truck	Petrol	Medium	Single-Pt FI	2-Way	PCV	<79K km	66	0.029	Euro I
Auto/Small Truck	Petrol	Light	Multi-Pt FI	3-Way	PCV	<79K km	117	0.120	Euro II
Auto/Small Truck	Petrol	Medium	Multi-Pt FI	3-Way	PCV	<79K km	120	0.052	Euro II
Auto/Small Truck	Propane	Light	Carb/Mixer	None	PCV	<79K km	396	0.006	Pre-Euro
Auto/Small Truck	Propane	Light	Carb/Mixer	None	PCV	80-161K km	397	0.003	Pre-Euro
Auto/Small Truck	Propane	Light	Carb/Mixer	3-Way	PCV	<79K km	423	0.003	Euro I
Auto/Small Truck	Diesel	Light	Pre-Chamber Inject.	Improved	None	<79K km	747	0.198	Euro I
Auto/Small Truck	Diesel	Light	Pre-Chamber Inject.	Improved	None	80-161K km	748	0.016	Euro I
Auto/Small Truck	Diesel	Light	Pre-Chamber Inject.	Improved	None	>161K km	749	0.003	Euro I
Auto/Small Truck	Diesel	Medium	Pre-Chamber Inject.	Improved	None	<79K km	750	0.094	Euro I
Auto/Small Truck	Diesel	Medium	Pre-Chamber Inject.	Improved	None	80-161K km	751	0.071	Euro I
Auto/Small Truck	Diesel	Medium	Pre-Chamber Inject.	Improved	None	>161K km	752	0.026	Euro I
Auto/Small Truck	Diesel	Heavy	Pre-Chamber Inject.	Improved	None	<79K km	753	0.023	Euro I
Auto/Small Truck	Diesel	Heavy	Pre-Chamber Inject.	Improved	None	>161K km	755	0.003	Euro I
Van/Jeep									
Auto/Small Truck	Diesel	Medium	Direct Injection	EGR+Improved	None	>161K km	761	0.02	Pre-Euro
Auto/Small Truck	Diesel	Medium	FI	EuroI	None	<79K km	786	0.02	Euro I
Auto/Small Truck	Diesel	Medium	FI	EuroI	None	80-161K km	787	0.01	Euro I
Auto/Small Truck	Diesel	Medium	FI	EuroI	None	>161K km	78	0.92	Euro I
Auto/Small Truck	Diesel	Heavy	FI	EuroI	None	<79K km	789	0.03	Euro I
3-Wheeler									
Small Engine	CNG/LPG	Heavy	4-Cycle, Carb	Catalyst	None	26-50K	1276	0.02	Pre-Euro
Small Engine	CNG/LPG	Heavy	4-Cycle, Carb	Catalyst	None	>50K	1277	0.98	Pre-Euro
Truck/Mini truck									
Truck/Bus	Diesel	Light	Pre-Chamber Inject.	None	None	>161K km	1073	0.09605	Pre-Euro
Truck/Bus	Diesel	Medium	Pre-Chamber Inject.	None	None	>161K km	1076	0.08145	Pre-Euro
Truck/Bus	Diesel	Heavy	Pre-Chamber Inject.	None	None	>161K km	1079	0.1775	Pre-Euro
Truck/Bus	Diesel	Light	Direct Injection	Improved	None	>161K km	1082	0.10275	Pre-Euro
Truck/Bus	Diesel	Medium	Direct Injection	Improved	None	>161K km	1085	0.08715	Pre-Euro
Truck/Bus	Diesel	Heavy	Direct Injection	Improved	None	>161K km	1088	0.1899	Pre-Euro
Truck/Bus	Diesel	Light	FI	Euro I	None	>161K km	1118	0.04135	Euro I
Truck/Bus	Diesel	Medium	FI	Euro I	None	>161K km	1121	0.03505	Euro I
Truck/Bus	Diesel	Heavy	FI	Euro I	None	>161K km	1124	0.0764	Euro I
Truck/Bus	Diesel	Light	FI	Euro II	None	80-161K km	1126	0.0304	Euro II
Truck/Bus	Diesel	Medium	FI	Euro II	None	80-161K km	1129	0.0258	Euro II
Truck/Bus	Diesel	Heavy	FI	Euro II	None	80-161K km	1132	0.0562	Euro II

**Table S2.** Parameters used for estimating fuel consumption for each type of brick kiln in the Kathmandu Valley

Type of Kilns	Number of Kilns	Annual average production <sup>a</sup> (bricks/plant/year)	Monthly average production <sup>b</sup> P <sub>j</sub> , (bricks/plant/month)	Average weight of a brick <sup>c</sup> W <sub>brick</sub> (kg per brick)	Specific energy consumption <sup>d</sup> E <sub>brick</sub> (MJ/kg-brick)	Specific energy density of coal U <sub>coal</sub> , (MJ/kg-coal)	Coal consumed BK <sub>j</sub> , kg-coal/plant/month
FCBTK	46	5719626	953271	2.03	1.30	27	93173
Hoffman	2	20000000	3333333	2.03	1.36	27	340840
VSBK	1	8000000	1333333	2.03	0.80	27	80198
Zigzag	63	5719626	953271	2.03	1.03	27	73822

a: The annual average production of each type of kiln is obtained from <http://doenv.gov.np/files/download/Report%20Brick%20Kiln%20%20Emission.pdf>;

b: Nepal brick kilns usually operate 6 months per year, running from December to May;

c: Brick weight in Kathmandu Valley is 2.03 kg on average (CEN, 2009);

d: The value of specific energy consumption is obtained from <http://www.ccacoalition.org/en/resources/factsheets-about-brick-kilns-south-and-south-east-a>

**Table S3a.** Emission factors (g/kg fuel) for a zigzag kiln

Compound (Formula)	Emission factors	Reference
EC	0.1118	Jayarathne et al. (2018)
OC	1.0577	
SO <sub>4</sub>	4.8201	
PM <sub>2.5</sub>	15.11	
Sulfur Dioxide (SO <sub>2</sub> )	12.7	Stockwell et al. (2016)
Nitric Oxide (NO)	1.28	
Nitrogen Dioxide (NO <sub>2</sub> )	$8.21 \times 10^{-2}$	
Acetylene (C <sub>2</sub> H <sub>2</sub> )	$1.65 \times 10^{-2}$	
Ethylene (C <sub>2</sub> H <sub>4</sub> )	$4.32 \times 10^{-2}$	
Propylene (C <sub>3</sub> H <sub>6</sub> )	$6.58 \times 10^{-2}$	
Methanol (CH <sub>3</sub> OH)	0.112	
Formic Acid (HCOOH)	$5.84 \times 10^{-2}$	
Acetic Acid (CH <sub>3</sub> COOH)	0.471	
Phenol (C <sub>6</sub> H <sub>5</sub> OH)	$1.54 \times 10^{-2}$	
1,3-Butadiene (C <sub>4</sub> H <sub>6</sub> )	$1.51 \times 10^{-2}$	
Isoprene (C <sub>5</sub> H <sub>8</sub> )	$2.46 \times 10^{-2}$	
Nitrous Acid (HONO)	$4.45 \times 10^{-2}$	
Methyl iodide (CH <sub>3</sub> I)	$2.01 \times 10^{-3}$	
1,2-Dichloroethene (C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub> )	$4.45 \times 10^{-5}$	
Methyl nitrate (CH <sub>3</sub> NO <sub>3</sub> )	$2.92 \times 10^{-3}$	
Ethane (C <sub>2</sub> H <sub>6</sub> )	$2.06 \times 10^{-3}$	
Propane (C <sub>3</sub> H <sub>8</sub> )	$1.97 \times 10^{-3}$	
i-Butane (C <sub>4</sub> H <sub>10</sub> )	$1.60 \times 10^{-3}$	
n-Butane (C <sub>4</sub> H <sub>10</sub> )	$1.92 \times 10^{-3}$	
1-Butene (C <sub>4</sub> H <sub>8</sub> )	$1.68 \times 10^{-3}$	
i-Butene (C <sub>4</sub> H <sub>8</sub> )	$1.47 \times 10^{-3}$	
trans-2-Butene (C <sub>4</sub> H <sub>8</sub> )	$1.44 \times 10^{-3}$	
cis-2-Butene (C <sub>4</sub> H <sub>8</sub> )	$9.65 \times 10^{-4}$	
i-Pentane (C <sub>5</sub> H <sub>12</sub> )	$3.70 \times 10^{-2}$	
n-Pentane (C <sub>5</sub> H <sub>12</sub> )	$3.26 \times 10^{-2}$	
1-Pentene (C <sub>5</sub> H <sub>10</sub> )	$1.60 \times 10^{-3}$	
trans-2-Pentene (C <sub>5</sub> H <sub>10</sub> )	$2.64 \times 10^{-2}$	
cis-2-Pentene (C <sub>5</sub> H <sub>10</sub> )	$9.01 \times 10^{-4}$	
3-Methyl-1-butene (C <sub>5</sub> H <sub>10</sub> )	$3.32 \times 10^{-4}$	
1,2-Propadiene (C <sub>3</sub> H <sub>4</sub> )	$2.15 \times 10^{-5}$	
n-Hexane (C <sub>6</sub> H <sub>14</sub> )	$2.16 \times 10^{-2}$	
n-Heptane (C <sub>7</sub> H <sub>16</sub> )	$3.04 \times 10^{-3}$	

**Table S3b.** Emission factors (g/kg fuel) for a zigzag kiln

Compound (Formula)	Emission factors	Reference
n-Octane (C <sub>8</sub> H <sub>18</sub> )	$1.58 \times 10^{-3}$	Stockwell et al. (2016)
n-Nonane (C <sub>9</sub> H <sub>20</sub> )	$2.42 \times 10^{-3}$	
n-Decane (C <sub>10</sub> H <sub>22</sub> )	$2.02 \times 10^{-3}$	
2,3-Dimethylbutane (C <sub>6</sub> H <sub>14</sub> )	$3.59 \times 10^{-3}$	
2-Methylpentane (C <sub>6</sub> H <sub>14</sub> )	$4.84 \times 10^{-3}$	
3-Methylpentane (C <sub>6</sub> H <sub>14</sub> )	$1.17 \times 10^{-2}$	
2,2,4-Trimethylpentane (C <sub>8</sub> H <sub>18</sub> )	$8.53 \times 10^{-4}$	
Cyclopentane (C <sub>5</sub> H <sub>10</sub> )	$8.53 \times 10^{-4}$	
Cyclohexane (C <sub>6</sub> H <sub>12</sub> )	$2.98 \times 10^{-3}$	
Benzene (C <sub>6</sub> H <sub>6</sub> )	$8.25 \times 10^{-3}$	
Toluene (C <sub>7</sub> H <sub>8</sub> )	$2.80 \times 10^{-2}$	
Ethylbenzene (C <sub>8</sub> H <sub>10</sub> )	$1.35 \times 10^{-2}$	
m/p-Xylene (C <sub>8</sub> H <sub>10</sub> )	$5.74 \times 10^{-2}$	
o-Xylene (C <sub>8</sub> H <sub>10</sub> )	$2.18 \times 10^{-2}$	
Styrene (C <sub>8</sub> H <sub>8</sub> )	$4.56 \times 10^{-3}$	
i-Propylbenzene (C <sub>9</sub> H <sub>12</sub> )	$4.07 \times 10^{-4}$	
n-Propylbenzene (C <sub>9</sub> H <sub>12</sub> )	$1.82 \times 10^{-3}$	
3-Ethyltoluene (C <sub>9</sub> H <sub>12</sub> )	$6.93 \times 10^{-3}$	
4-Ethyltoluene (C <sub>9</sub> H <sub>12</sub> )	$3.69 \times 10^{-3}$	
2-Ethyltoluene (C <sub>9</sub> H <sub>12</sub> )	$2.30 \times 10^{-3}$	
1,3,5-Trimethylbenzene (C <sub>9</sub> H <sub>12</sub> )	$4.30 \times 10^{-3}$	
1,2,4-Trimethylbenzene (C <sub>9</sub> H <sub>12</sub> )	$5.59 \times 10^{-3}$	
1,2,3-Trimethylbenzene (C <sub>9</sub> H <sub>12</sub> )	$2.03 \times 10^{-3}$	
alpha-Pinene (C <sub>10</sub> H <sub>16</sub> )	$1.49 \times 10^{-3}$	
beta-Pinene (C <sub>10</sub> H <sub>16</sub> )	$1.31 \times 10^{-3}$	
Ethanol (C <sub>2</sub> H <sub>6</sub> O)	$4.84 \times 10^{-3}$	
Acetaldehyde (C <sub>2</sub> H <sub>4</sub> O)	$6.94 \times 10^{-2}$	
Acetone (C <sub>3</sub> H <sub>6</sub> O)	$1.46 \times 10^{-1}$	
Butanal (C <sub>4</sub> H <sub>8</sub> O)	$2.19 \times 10^{-3}$	
Butanone (C <sub>4</sub> H <sub>8</sub> O)	$2.29 \times 10^{-3}$	



**Table S4.** Composite emission factors of different vehicle types during running in the Kathmandu Valley, April 2015 (g/km)

Vehicle types	CO	SO <sub>2</sub>	NO <sub>x</sub>	NMVOC	PM
Motorcycle	7.78	0.01	0.20	2.21	0.11
Bus/Minibus	17.46	0.22	33.57	5.16	9.38
Taxi	37.72	0.04	1.61	4.69	0.01
Car/Pickup	3.72	0.06	2.47	0.77	0.28
Van/Jeep	3.97	0.14	4.51	0.62	1.03
3-wheeler	6.86	3.14E-04	0.26	0.21	0.01
Truck/Mini truck	99.79	0.80	151.85	20.44	46.49

**Table S5.** Composite emission factors of different vehicle types during start-up in Kathmandu Valley, April 2015 (g/start)

Vehicle types	CO	SO <sub>2</sub>	NO <sub>x</sub>	NMVOC	PM
Motorcycle	9.11	0.00	1.91	1.91	0.12
Bus/Minibus	0.77	0.00	0.07	0.07	2.91
Taxi	27.60	0.00	3.07	3.07	0.01
Car/Pickup	6.20	0.00	0.51	0.51	0.11
Van/Jeep	1.93	0.00	0.15	0.15	0.27
3-wheeler	4.00	3.92E-06	0.10	0.10	0.00
Truck/Mini truck	3.90	0.01	0.29	0.29	15.51

**Table S6.** Total daytime rainfall (mm) and average wind speed from 9:00 am - 18:00 pm during two episode periods.

Date	15-Apr	16-Apr	18-Apr	19-Apr	20-Apr	21-Apr
Rainfall (mm)	6.4	0	19.0	0	0	6.4
Wind speed (m/s)	1.5	2.4	2.3	2.7	3.9	4.3