A new high resolution technology-based bottom-up emissions inventory for Nepal

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Air Pollution Sources in Nepal: Relative Roles? Mitigation?

Many sources are under-charaterized.

Comprehensive Emission Inventory Development for Nepal

Base year:	2011 (plus past trends and future projections)
Species (12):	• Aerosols : PM_{10}, $PM_{2.5}$, BC, OC, SO_2 • Ozone precursor: NO_X (NO and NO_2), NMVOC (speciated) • Trace gases: SO_2, CO, NH_3 • Greenhouse gases: CO_2, CH_4, N_2O
Resolution:	• Sub-national level (Districts, Municipalities, Villages) • Resolution : 1km × 1km, yearly, monthly, hourly
Sectors (6)	• Residential (cooking, heating, lighting, water boiling) • Industrial (point sources, others) • Commercial (academic inst., gov. inst, service sector, hotels, restaurants, hospitals) • Transport (road network) • Agricultural (residue burning, pumps, tractors etc,) • Trace/garbage burning

Emission Inventory Methodology

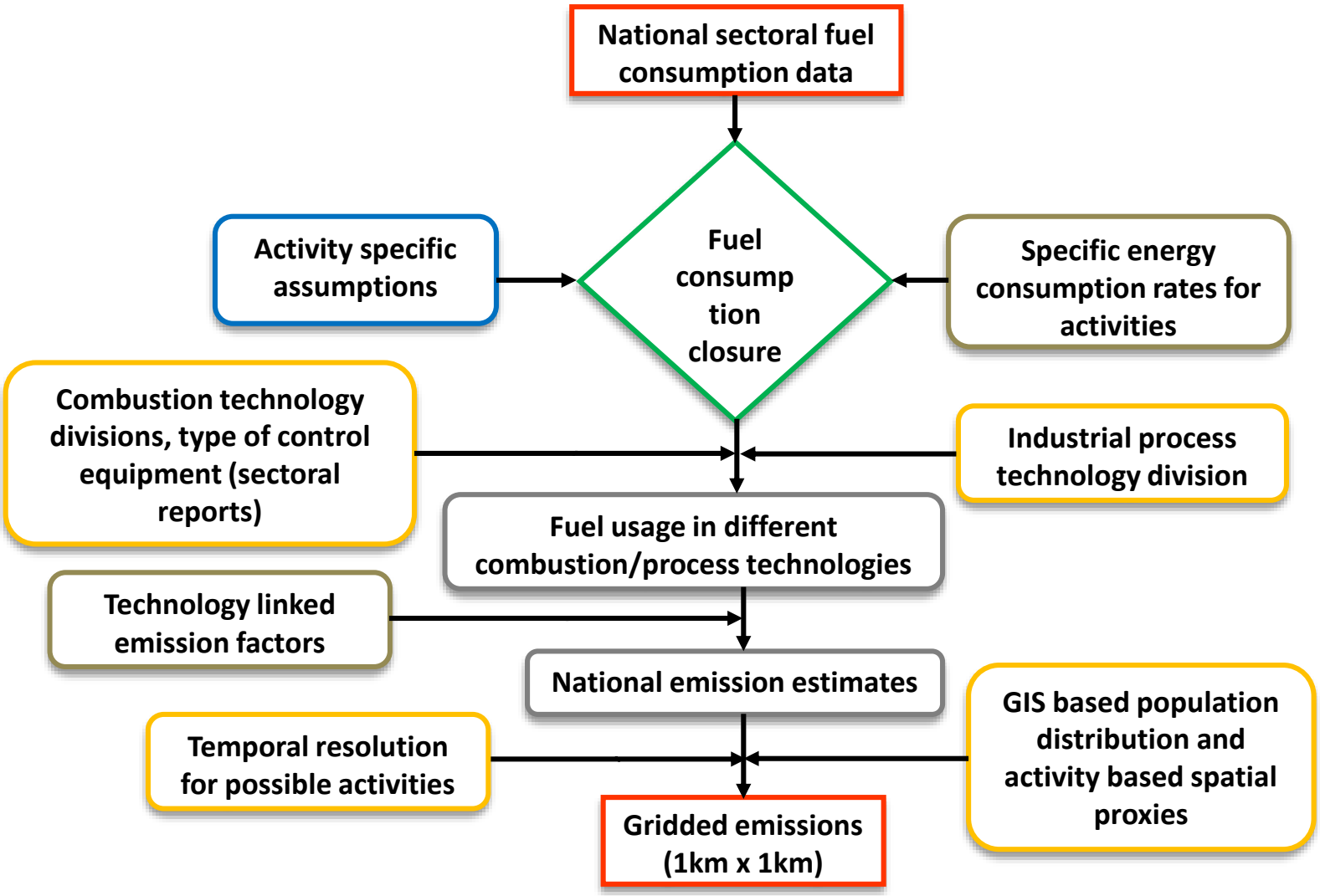
$$E_{i,s} = \sum_{f,t} F_{s,f,t} \times EF_{i,s,f,t} + \sum_{p} A_{s,p} \times EF_{i,s,p}$$

Combustion-related **process-related**

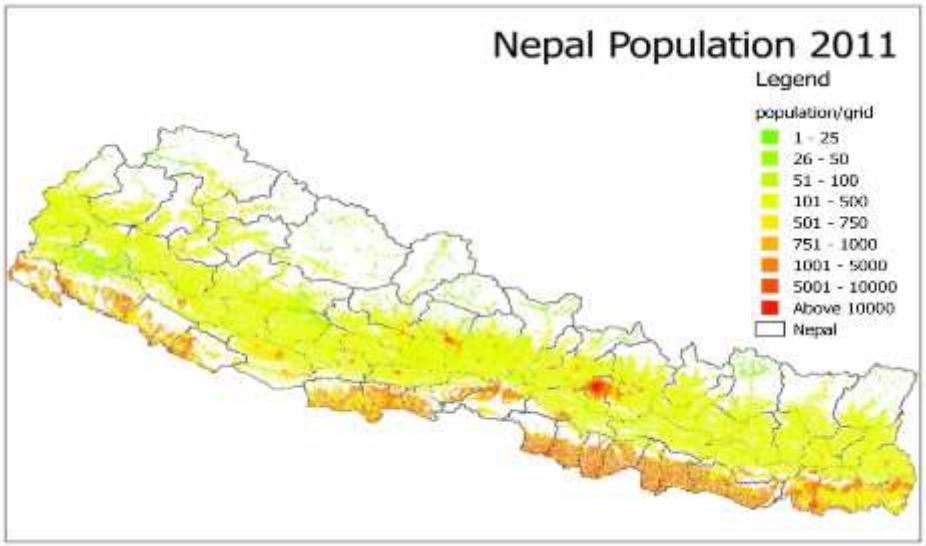
E = Emissions in (Gg/yr)
i = Pollutant
s = Sector
F = Fuel consumption for energy transformation
f = Type of fuel being combusted
t = Combustion technologies

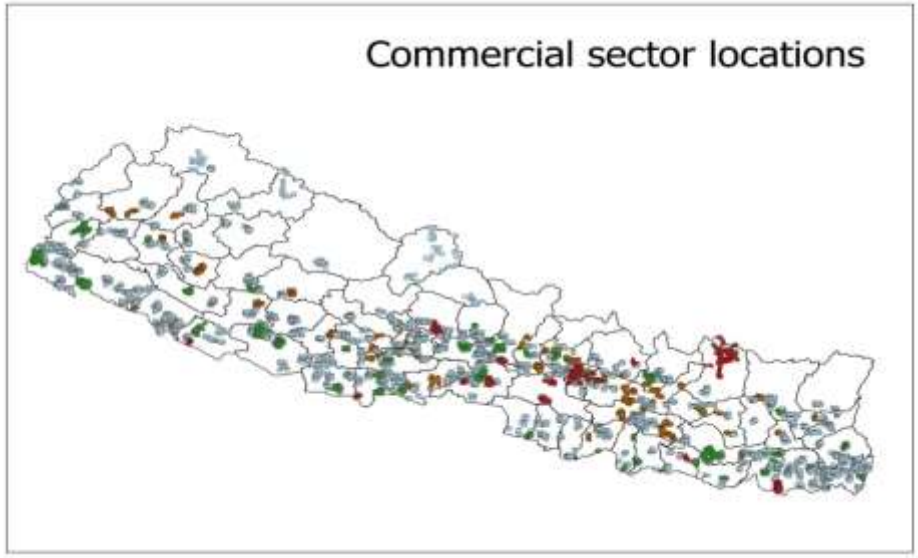
A = Activity
p = Process/fugitive
EF= Emission factor based on fuel consumption or process/fugitive activity

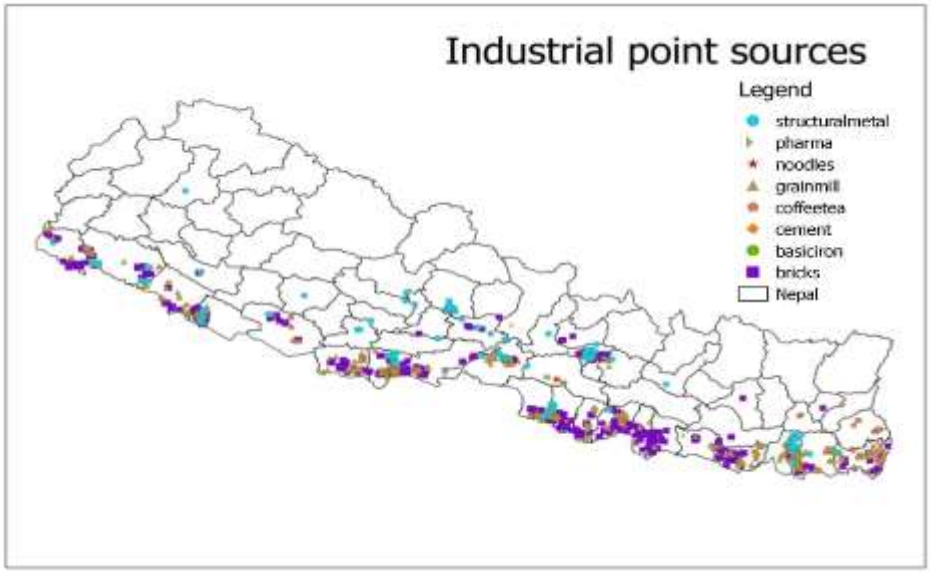
Emission Inventory Methodology

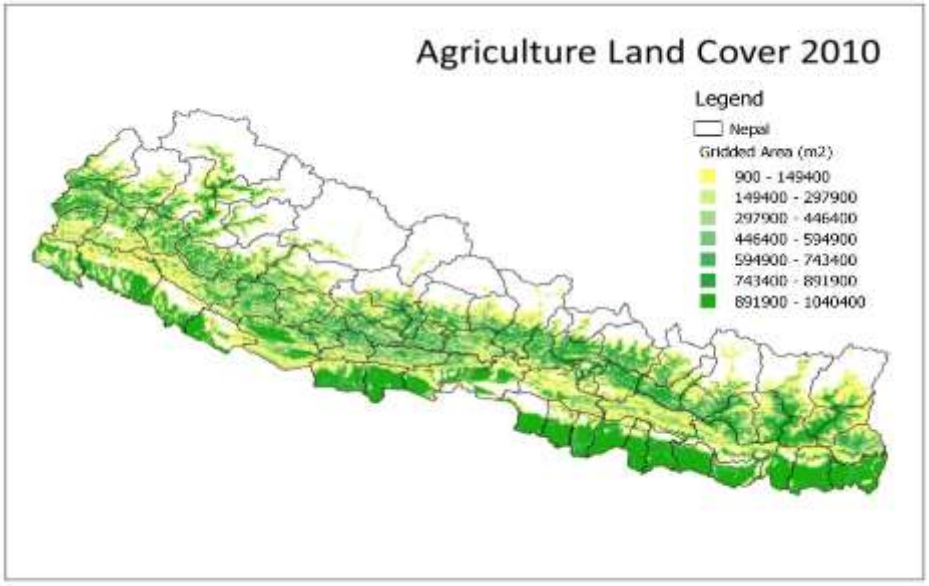


Key proxies used in EI development

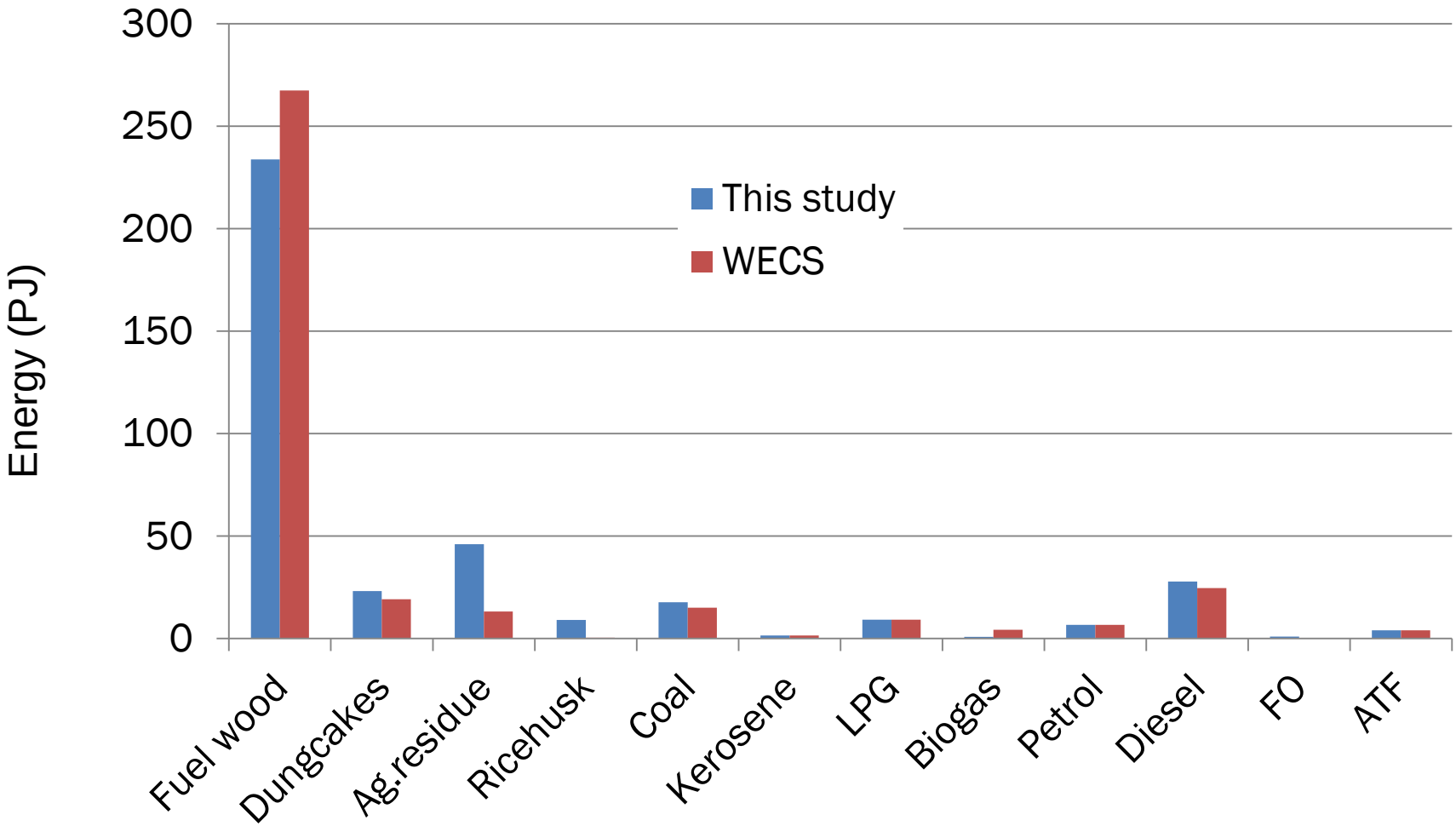






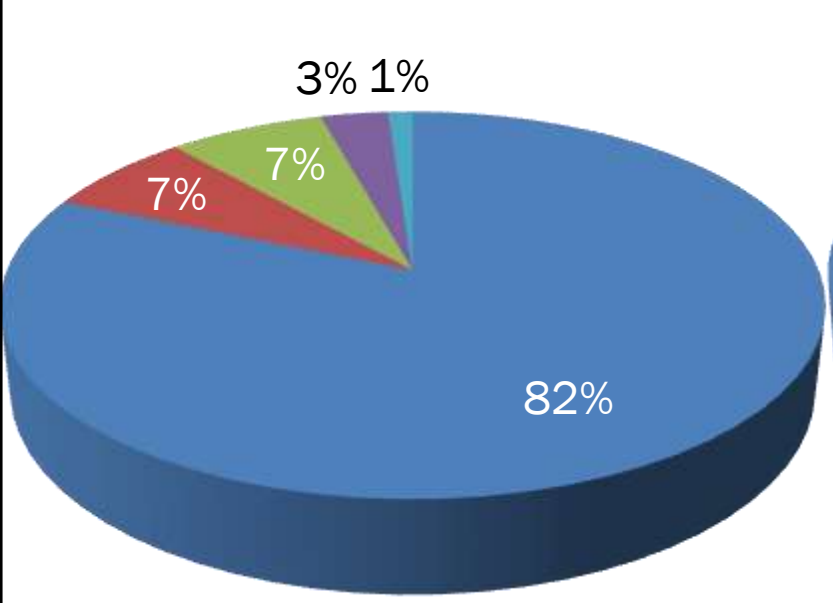


Energy consumption in Nepal: National Level (Fuel)



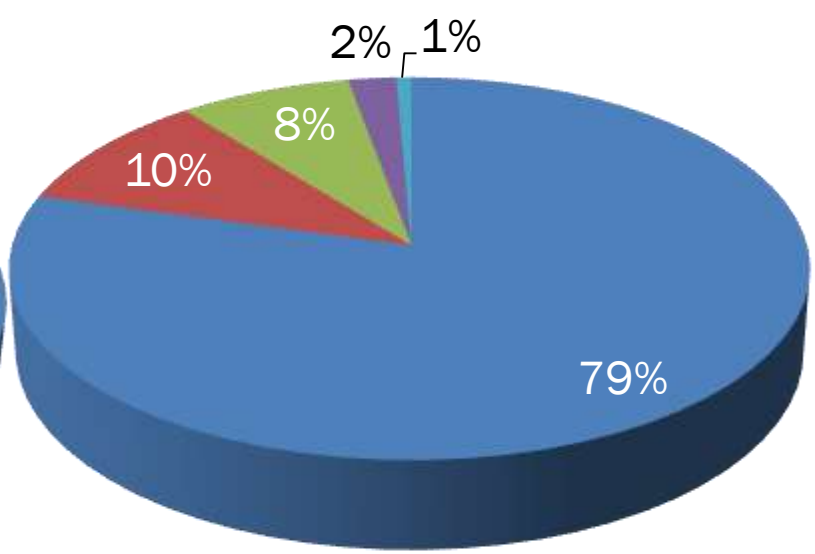
Biomass (mainly firewood) is the dominant energy source in Nepa

Energy consumption in Nepal: National Level (Sector)



365.44 PJ

WECS



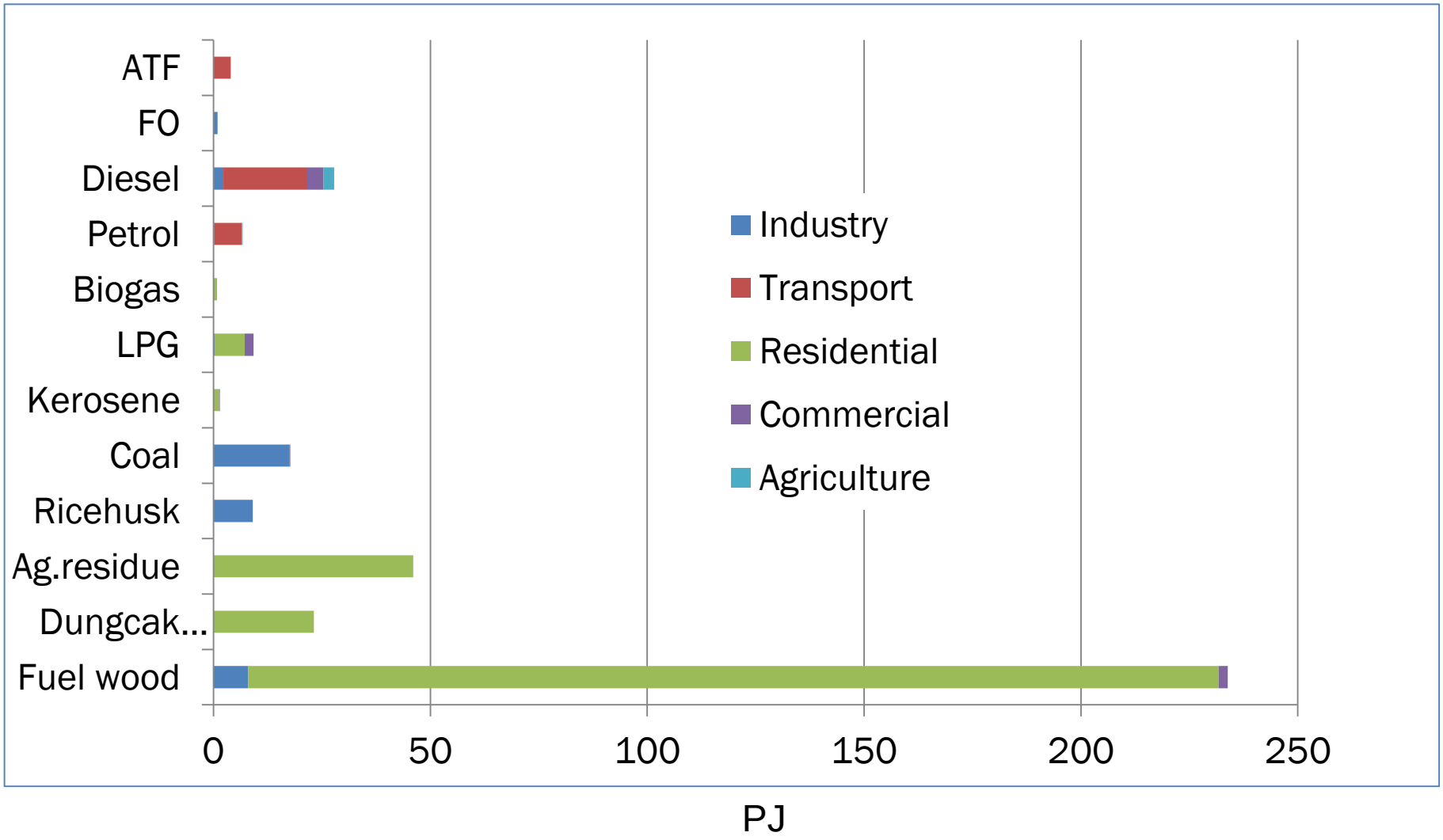
380.75 PJ

This study

Residential
Industry
Transport
Commercial
Agriculture (diesel)

Residential sector is the dominant energy consumer in Nepal

Energy consumption in Nepal: National Level (Fuel-Sector)



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Sectoral Emissions (ton)

	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	$PM_{2.5}$	BC	OC	SO_2
Industry	3306535	6723	106	3991	101030	8887	10298	2844	2103	10420
Transport	1696343	923	16	45305	119374	18290	3840	2195	1128	652
Residential	25308688	101563	1911	14528	1340323	168493	91154	14352	38941	3085
Commercial	584956	706	22	3540	13871	1892	633	137	276	147
Agriculture	179404	94	1	3944	2490	832	725	478	152	39
Total	31075926	110009	2057	71308	1577088	198394	106650	20007	42602	14343

Not yet included (still working on completion):
Agro-residue burning and garbage burning

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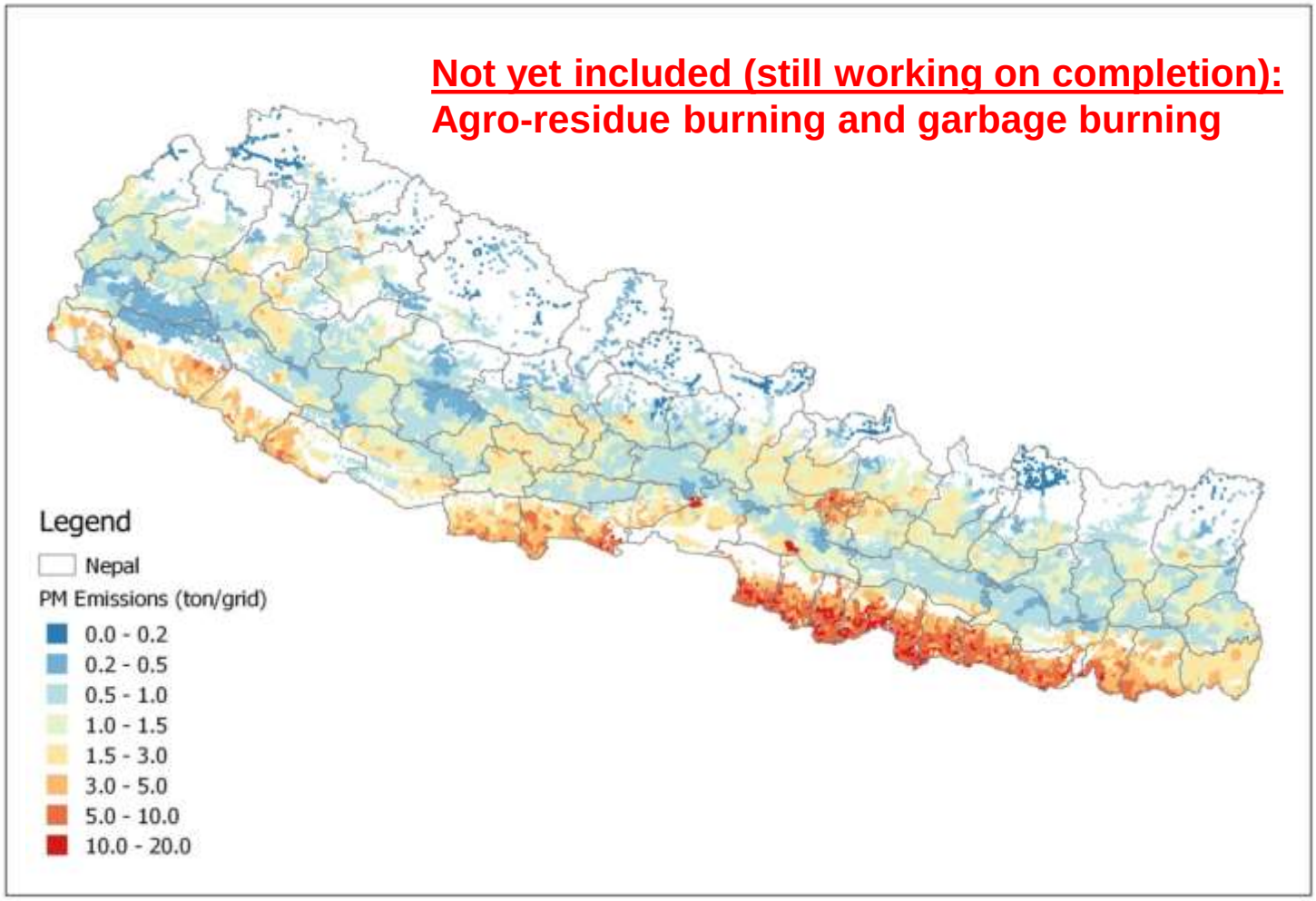
	Emissions in Gg (except CO_2 in Tg)													
	CO_2	CH_4	N_2O	NOx	CO	NMVOC	PM_{10}	$PM_{2.5}$	BC	OC	SO_2	NH_3	Source	
2000	39	917		55	2087	346			21	135	38	168	Streets et al., 2003	TRACE-P
2000				41	2404	206			27	136	26		Ohara et al., 2007	REAS1.11
2000	28	771	41	90	1717	349	117	110	21	85	26	223	Kurokawa et al., 2013	REAS2
2001	28	772	41	91	1768	359	121	113	22	87	26	225	Kurokawa et al., 2013	REAS2
2002	29	784	42	93	1796	369	124	117	23	90	24	231	Kurokawa et al., 2013	REAS2
2003	29	794	43	95	1843	377	128	120	23	92	25	235	Kurokawa et al., 2013	REAS2
2004	30	806	46	101	1879	386	130	122	24	94	26	247	Kurokawa et al., 2013	REAS2
2005	31	814	42	96	1939	396	135	125	24	96	27	236	Kurokawa et al., 2013	REAS2
2006	32	826	43	100	1985	405	138	128	25	98	28	242	Kurokawa et al., 2013	REAS2
2006				27	1659	251	205	186	21	103	31		Zhang et al., 2009	INTEX-B
2007	32	825	43	100	2028	415	142	131	25	100	29	244	Kurokawa et al., 2013	REAS2
2008	33	852	42	104	2080	425	146	135	26	102	30	245	Kurokawa et al., 2013	REAS2
2009														
2010														
2011	**31**	**110**	**2**	**71**	**1577**	**198**		**107**	**20**	**43**	**14**		**Sadavarte et al., 2017**	**IASS**

Spatial distribution (1km x 1km) of $PM_{2.5}$ emissions (Year 2011)



Joint study by IASS, ICIMOD and CDES/TU

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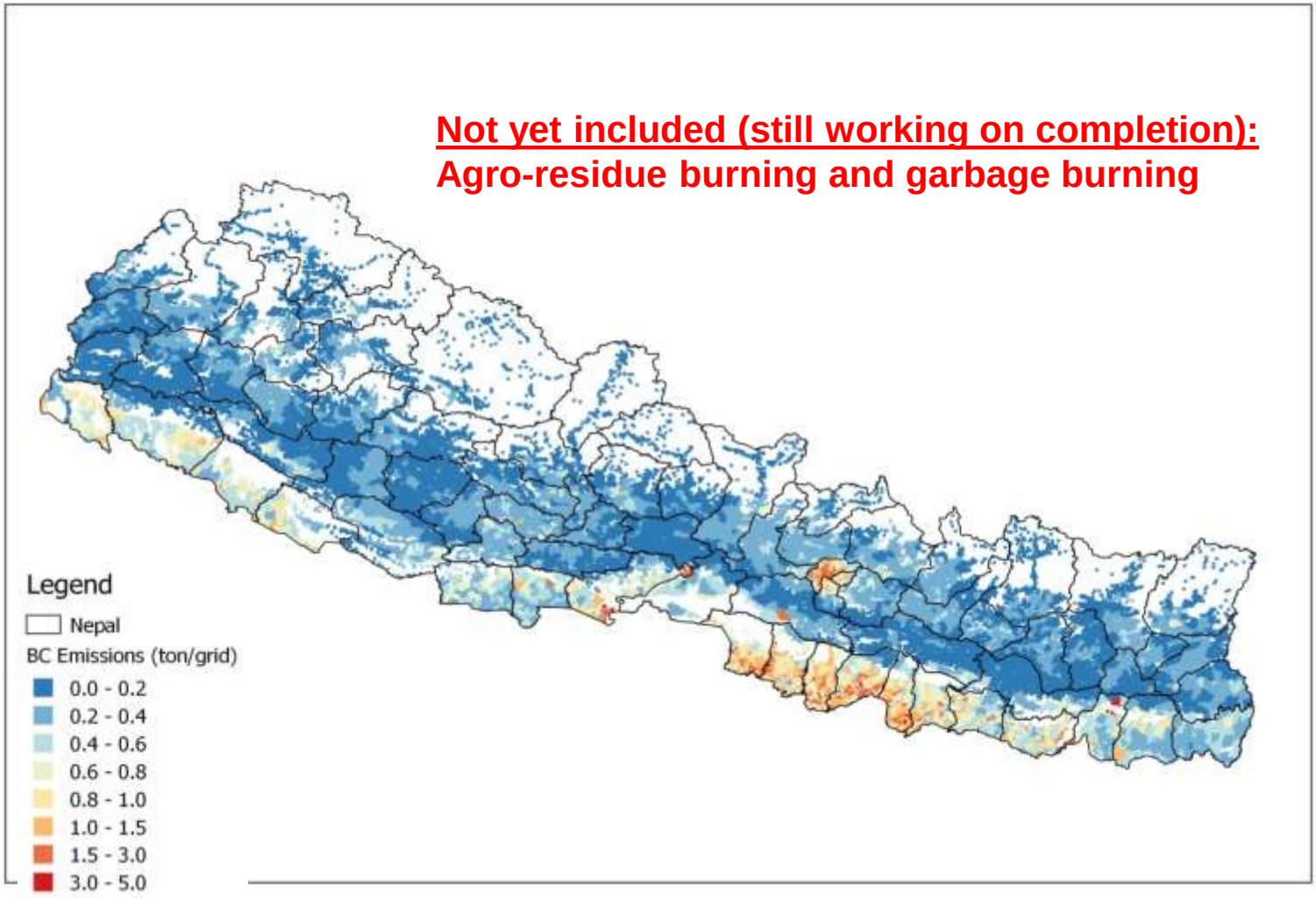
Spatial distribution (1km x 1km) of BC emissions (Year 2011)



Joint study by IASS, ICIMOD and CDES/TU

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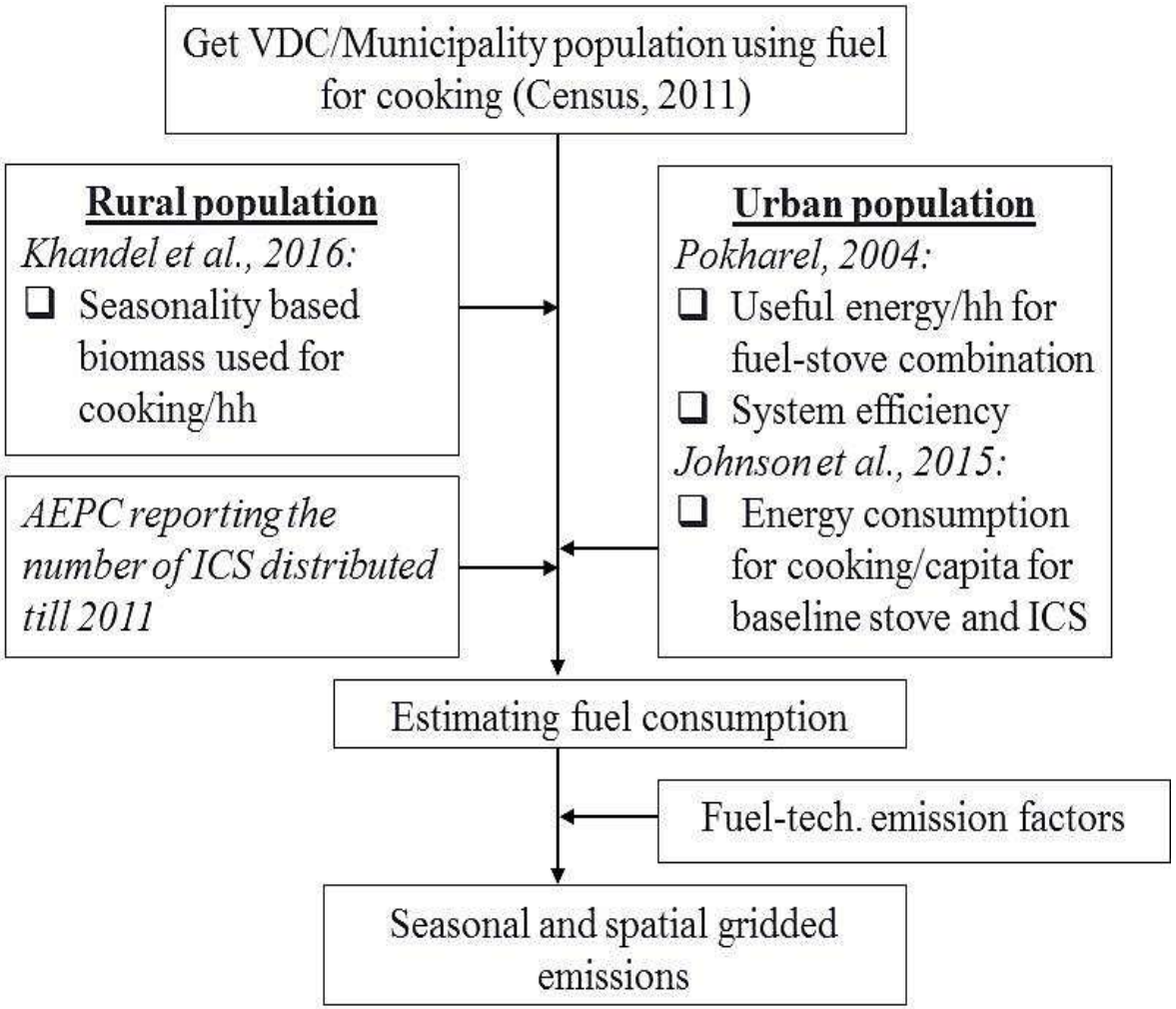
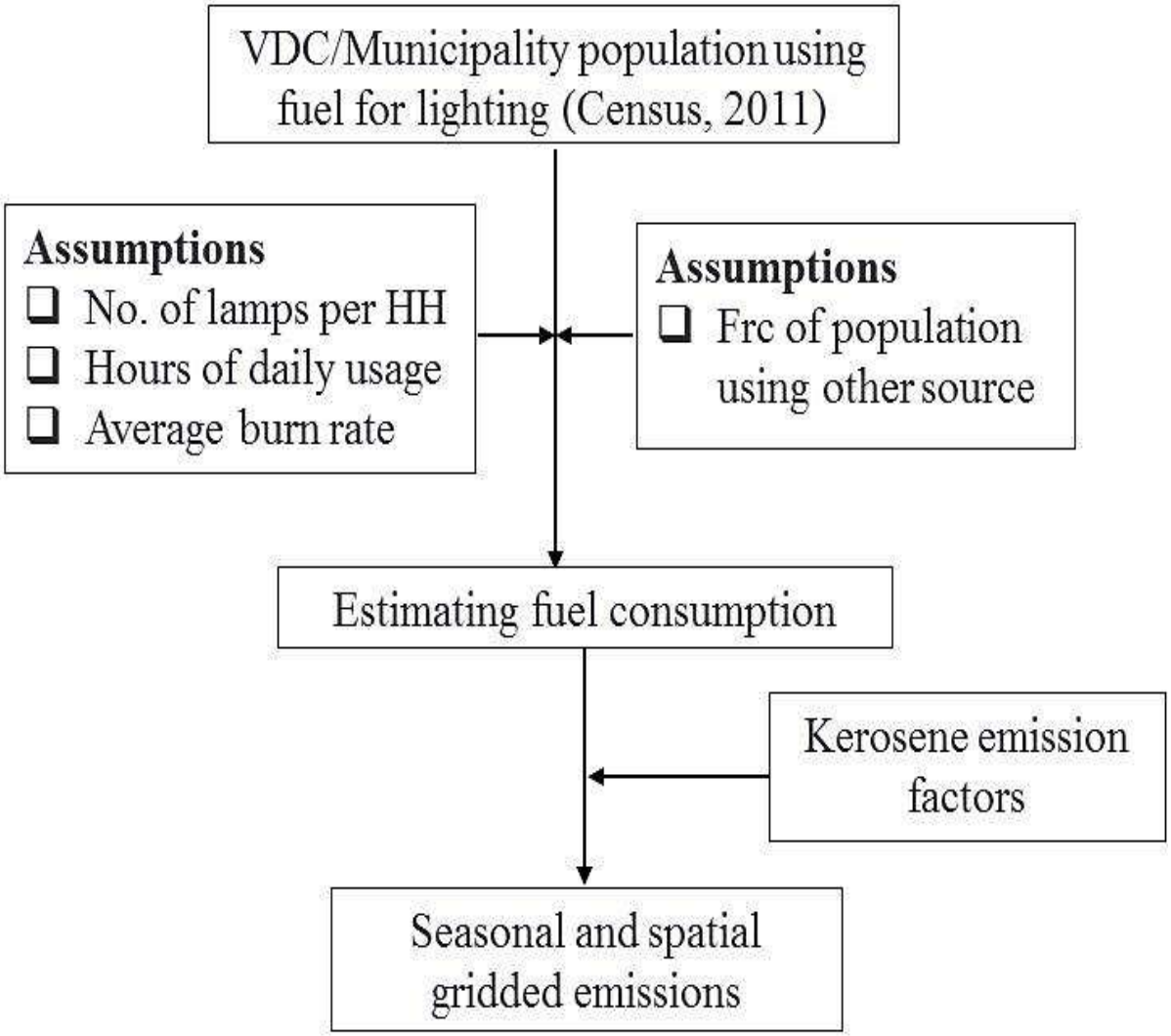
Thank You

Extras

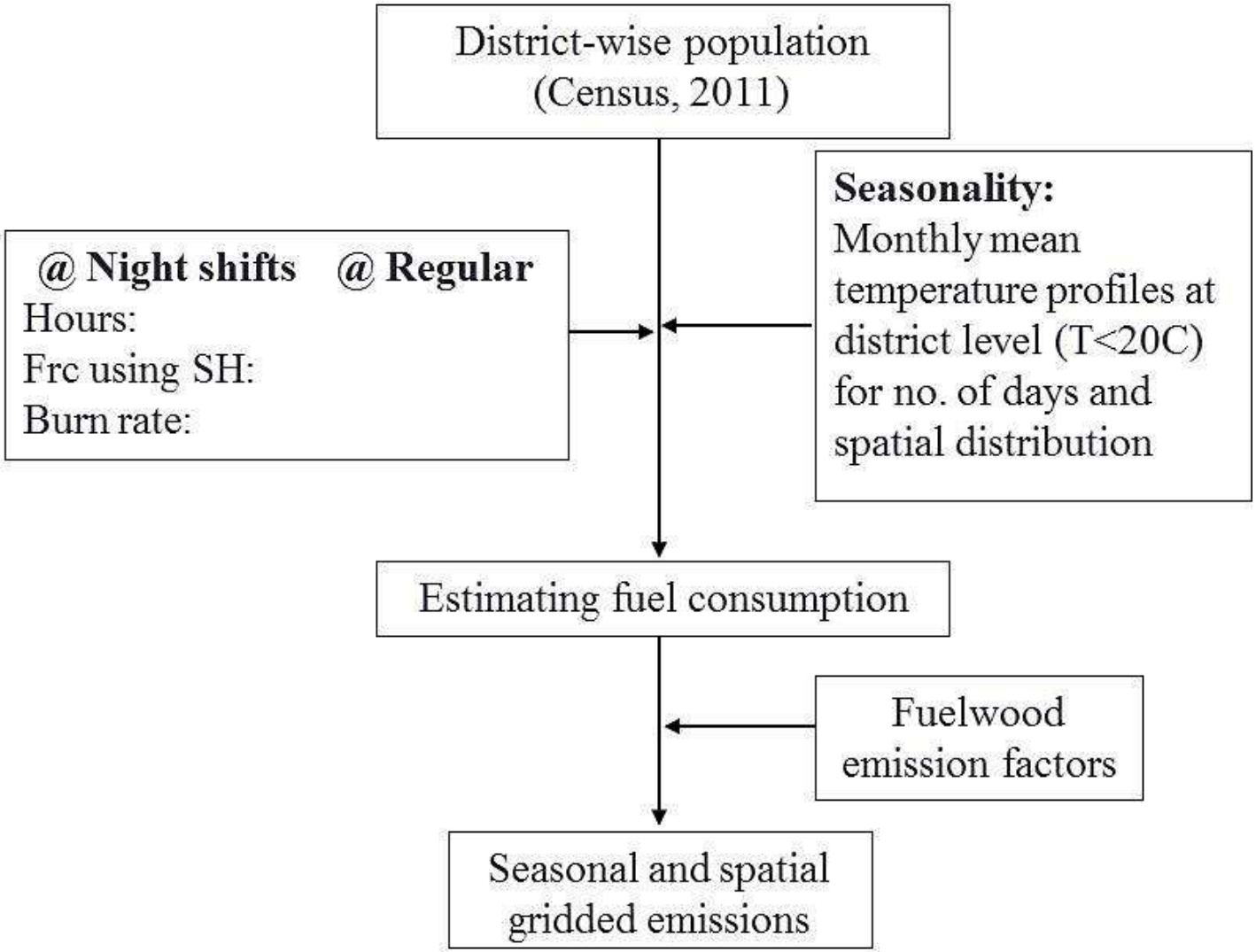
Methodology: Residential cooking



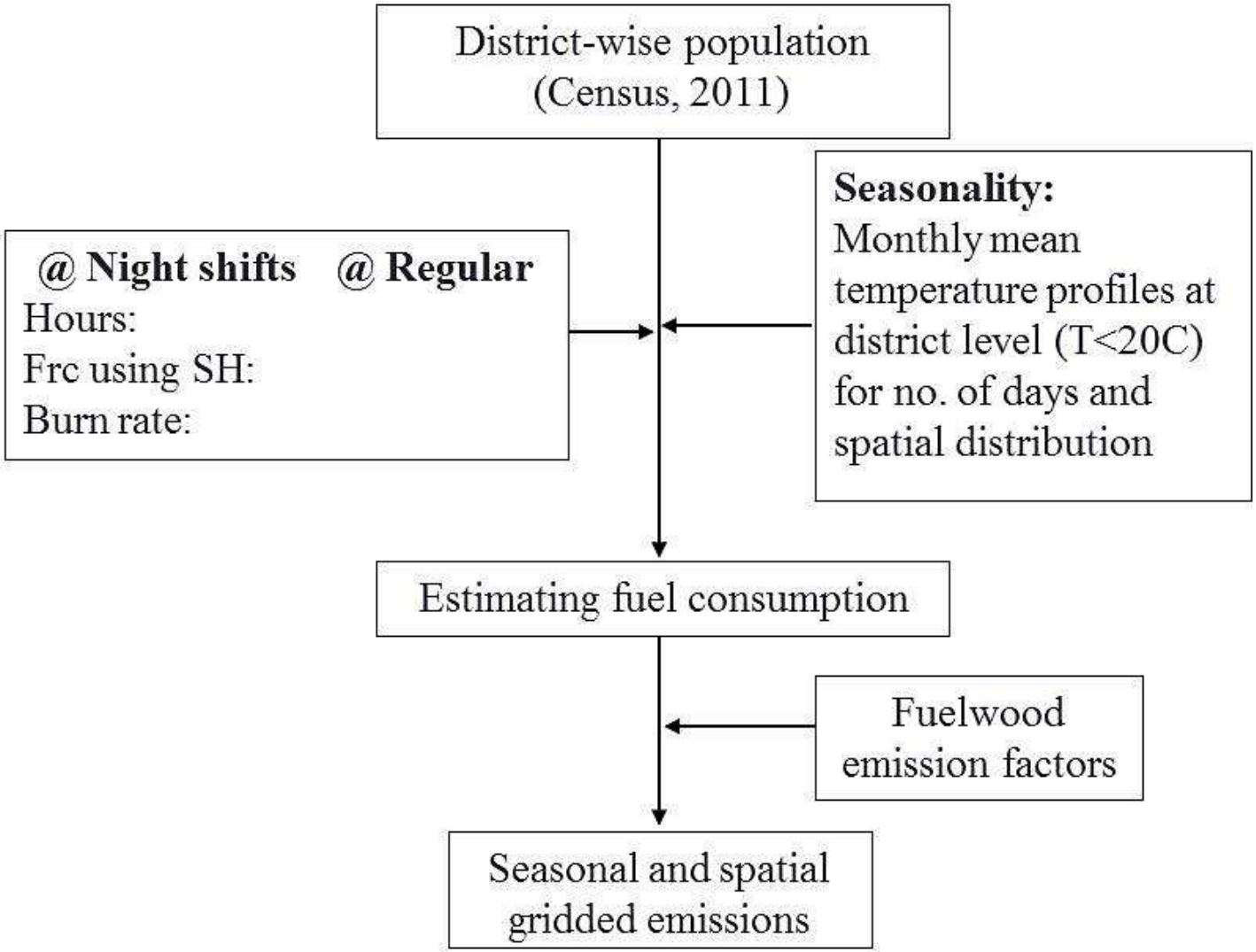
Methodology: Residential lighting



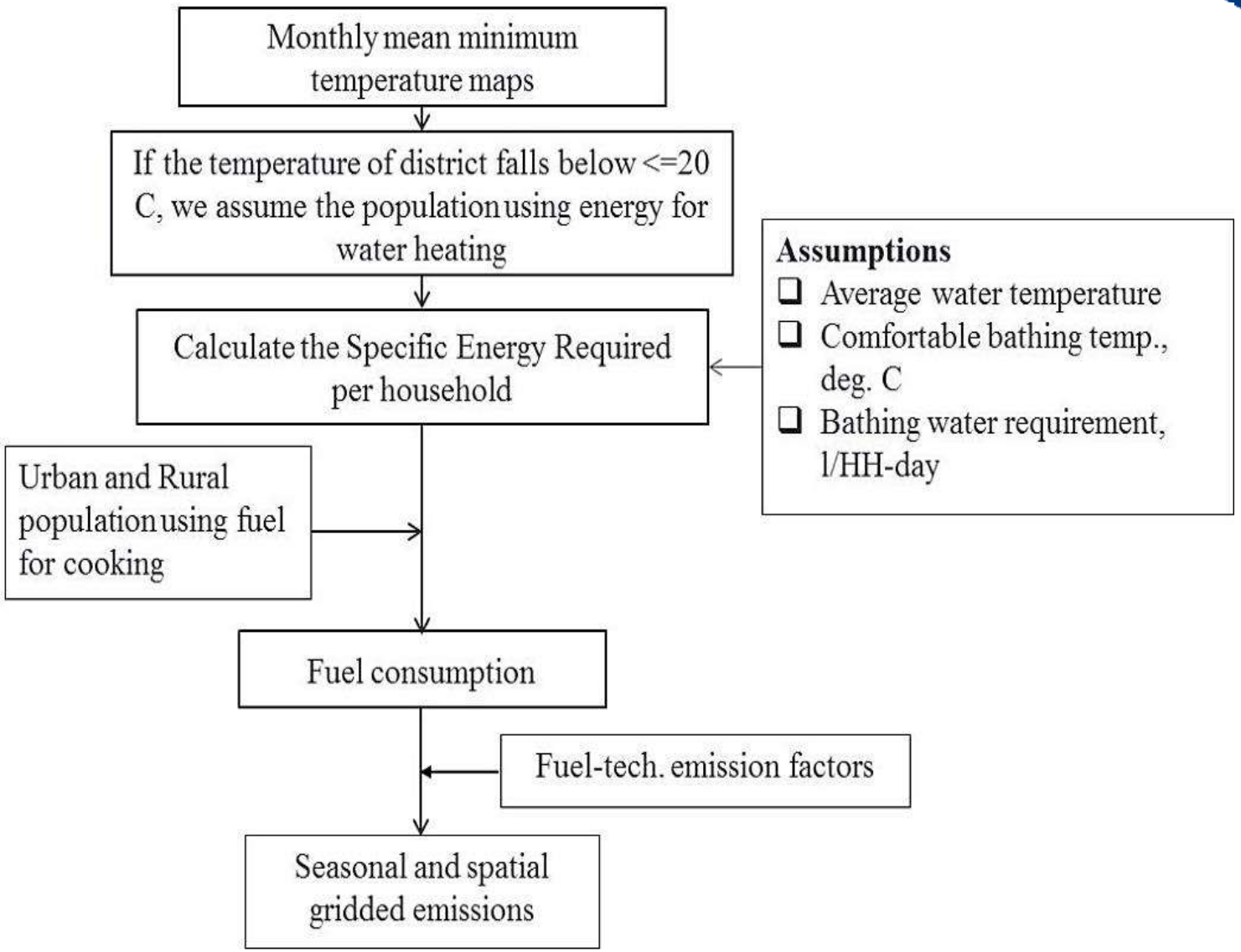
Methodology: Residential heating



Emission Inventory Methodology: Residential heating



Methodology: Residential water boiling



Methodology: Transport

$$E_i = \sum_{c} \sum_{v} \sum_{c,v} V_{c,v} \times P_c \times FE_c \times EF_{i,c,v}$$

α and L_{50} from Pandey and Venkataraman, 2014. α and L_{50} for Nepal are being estimated.

$V_{C,V}$ – On-road vehicle population for category 'c' and vintage 'v'

On-road vehicles = Sales(yy) × SuF(s)

SuF(s) – Survival fraction = Su(s)/Su(0)

$$Su(s) = \frac{1}{1 + \exp[\alpha_{ret}(1 - s/L_{50,ret})]}$$

Su(s) – survival rate; α – shape factor;

L_{50} – age at which 50% vehicles have retired;

[Yan et al., 2011; Pandey and Venkataraman, 2014]

P_C – Passenger kilometer travelled (km)

Modelled using the study Shreejan et la., 2013 for different vehicle categories

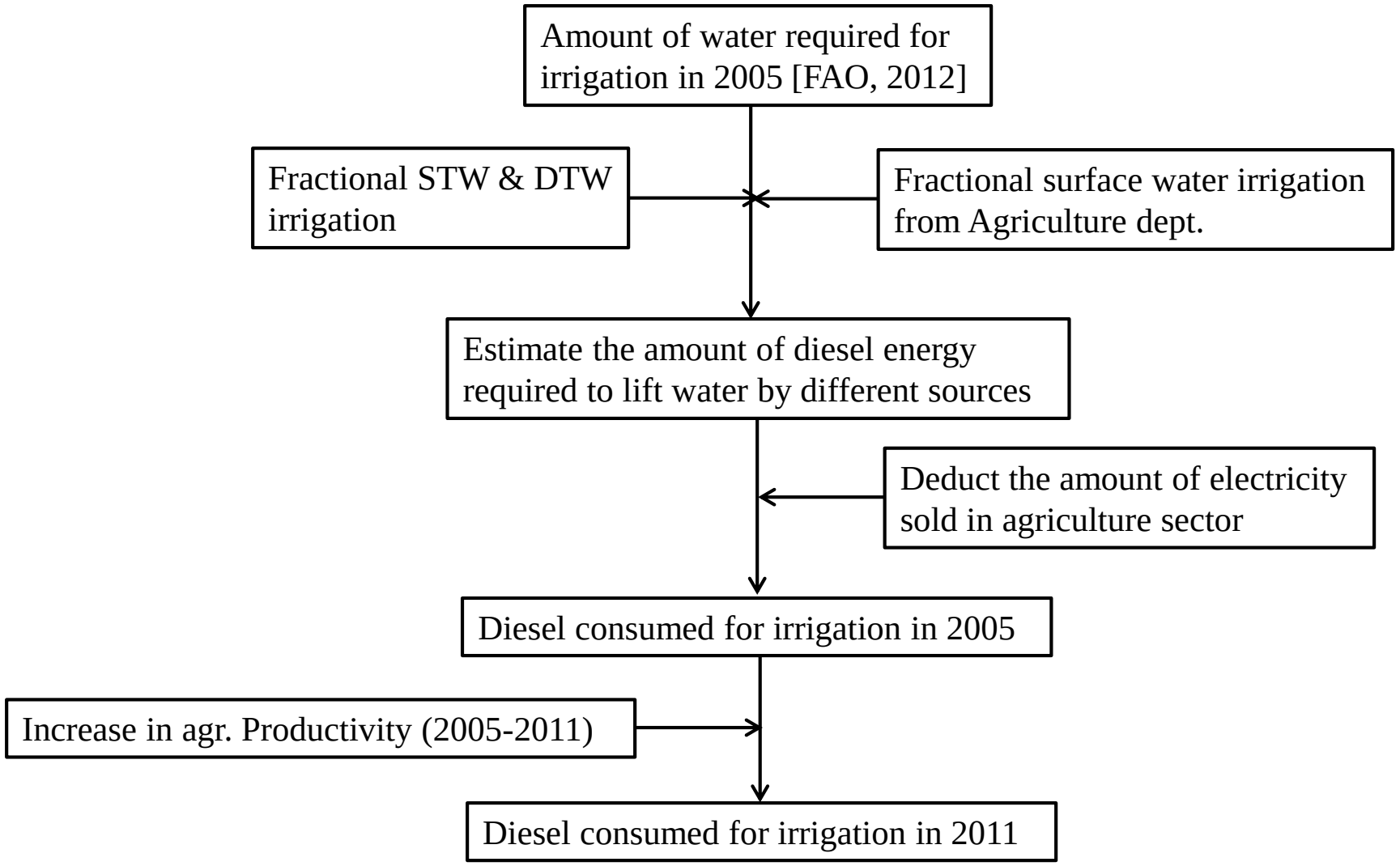
FE_C – Fuel efficiency (km/l)

Compiled and averaged from literature reporting fuel efficiency for Nepal vehicles

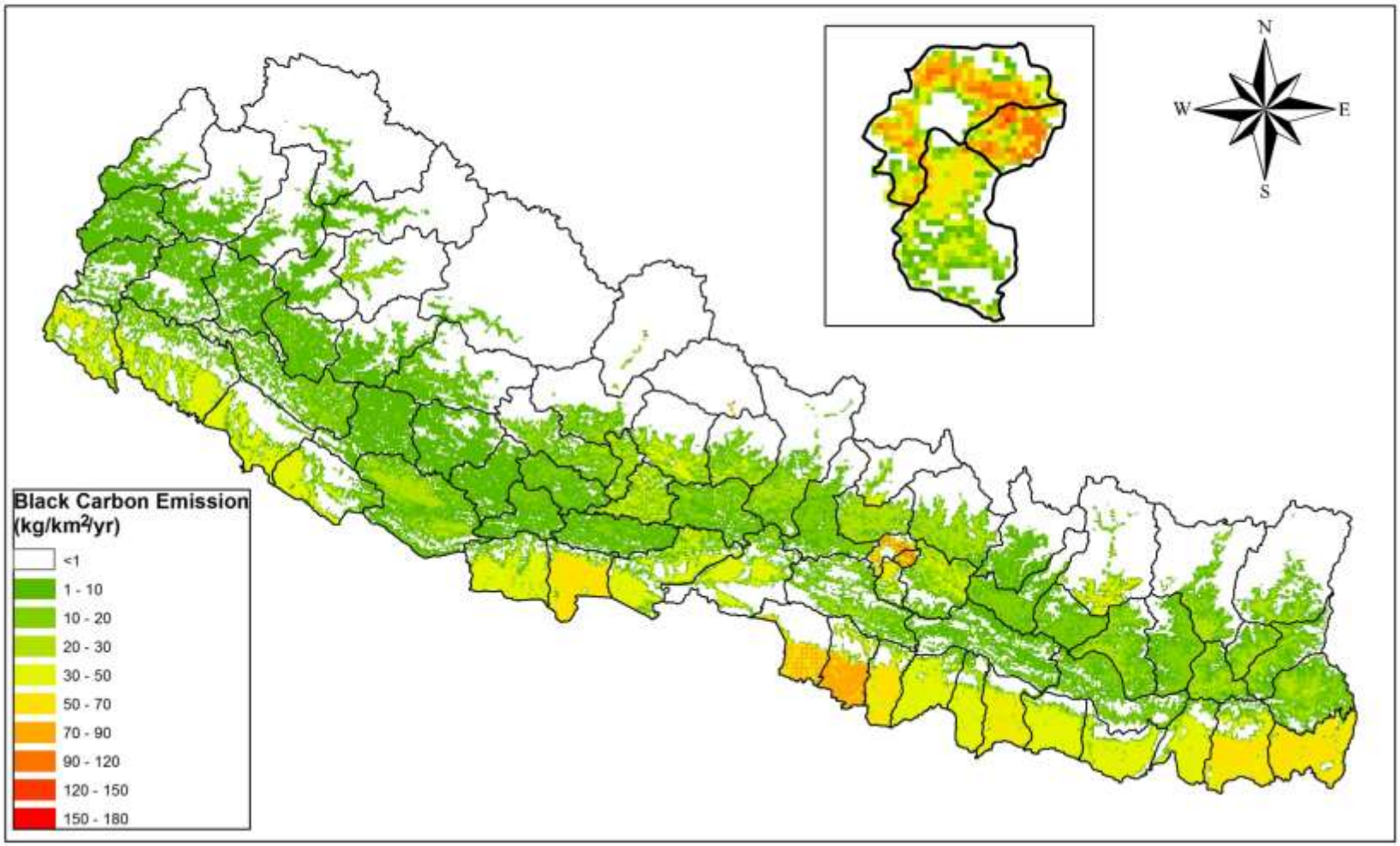
EF_C – Emission factors (g/kg)

Currently the Indian dynamometer measured emission factors are used from Pandey and Venkataraman, 2014. For Nepal these needs to be examined and estimated.

Methodology: Agriculture (pumps)



Grid (1x1 km) wise Black Carbon Emissions Flux from Agricultural Residue Burning (2008/2009)



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Technology-wise Emissions (ton)

Technologies	Energy (TJ)	CO2	CH4	N2O	NOX	CO	NMVOC	PM2.5	BC	OC	SO2
TCS (Firewood)	156163	12660861	45979	840	7459	712445	64743	38495	6458	18062	746
Openburning (wood)	46373	3759713	13654	249	2215	211565	19226	11431	1918	5363	221
TCS (Ag.res)	46036	4772181	27783	180	4032	240332	31107	18583	3172	7868	586
ICS (Firewood)	23305	1368704	4971	91	0	77019	9662	4162	698	1953	81
TCS (Dungcake)	16939	1627005	6961	488	467	62133	37564	15306	549	4816	1369
FCBTK (Coal+wood)	13179	1170815	1290	9	355	20129	1011	2427	2041	83	8548
Furnace (Ricehusk)	9073	1009555	3396	62	551	52628	4783	2783	467	1306	55
LPG stove	9008	564387	9	27	0	2726	3439	58	2	10	59
Truck	6973	775442	99	5	23528	21339	4377	2396	1581	503	372
Bus	6620	163495	3	2	11672	5306	1273	293	194	62	144
Furnace (Wood)	6550	463460	1683	31	273	26080	2370	1404	236	659	27
Openburning (Dungcake)	6213	774776	2814	51	456	43598	3962	2356	395	1105	46
DG set (Diesel+FO)	4310	302937	14	2	5665	1505	145	85	56	18	336
Cement kiln (Coal)	4177	293595	0	0	0	0	11	3483	26	32	517
2-Wheeler	3791	260524	782	0	4571	77390	10265	554	28	438	16
Cars	2688	154845	6	7	600	10338	923	4	1	2	9
Mini Truck/Pick Up	2687	123381	10	0	519	819	427	125	82	26	29
Boiler (Diesel)	2328	160323	0	2	142	36	1	2	13	0	33
Microbus/Minibus	1514	69495	6	0	292	461	240	70	46	15	16
Boiler (Coal)	1167	82043	1	1	185	105	1	96	19	4	720
Pumps (Diesel)	1159	79088	66	0	310	422	161	219	144	46	17
Tractors (Diesel)	1045	72567	16	1	2875	1613	521	383	253	81	15
Tractor/Tiller	994	110580	14	1	3355	3043	624	342	226	72	53

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Technology-wise Emissions (ton) (continued)

Technologies	Energy (TJ)	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	$PM_{2.5}$	BC	OC	SO_2
Biogas stove	817	0	0	0	0	0	0	0	0	0	0
Kerosene stove	778	50436	11	2	0	674	288	10	3	6	0
Kerosene lamps	636	38276	4	1	0	152	205	1285	1244	6	0
Cars/Jeeps/Van	563	38581	3	0	767	678	161	56	37	12	12
Oilboiler (FO)	434	31702	0	0	253	68	17	15	10	5	6
Clamps (Coal+wood)	388	33005	346	0	5	1328	555	53	10	7	231
TCS (Coal)	241	23135	76	2	0	2640	101	50	16	20	69
Threshers (Diesel)	220	15299	3	0	606	340	110	81	53	17	3
Gas furnace (LPG)	212	13261	0	1	0	64	81	1	0	0	1
Pumps (Gasoline)	140	9556	8	0	37	51	19	26	17	6	2
Power tillers (Diesel)	42	2895	1	0	115	64	21	15	10	3	1
Biogas lamps	0	7	0	0	0	0	0	0	0	0	0
TOTAL	**376763**	**31075926**	**110009**	**2057**	**71308**	**1577088**	**198394**	**106650**	**20007**	**42602**	**14343**

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