GHG Inventory report for Electricity generation and consumption in India

2009-10

cBalance Solutions Pvt. Ltd.

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1. Introduction

This report presents state wise emission factors for electricity generation as well as their respective AT&C losses. To enable accurate calculation of emissions by end users in each state the two factors are also combined to present an emission factor for end user consumption of electricity in each state in India. This report, brought

out by cBalance Solution Pvt. Ltd., also highlights comparative emissions of all states taking into account each ones specific emission factor which with further analysis can be used as a tool for progressive national policy making in order to help India achieve its goal of 20-25% emissions reduction from 2005 levels by 2020.

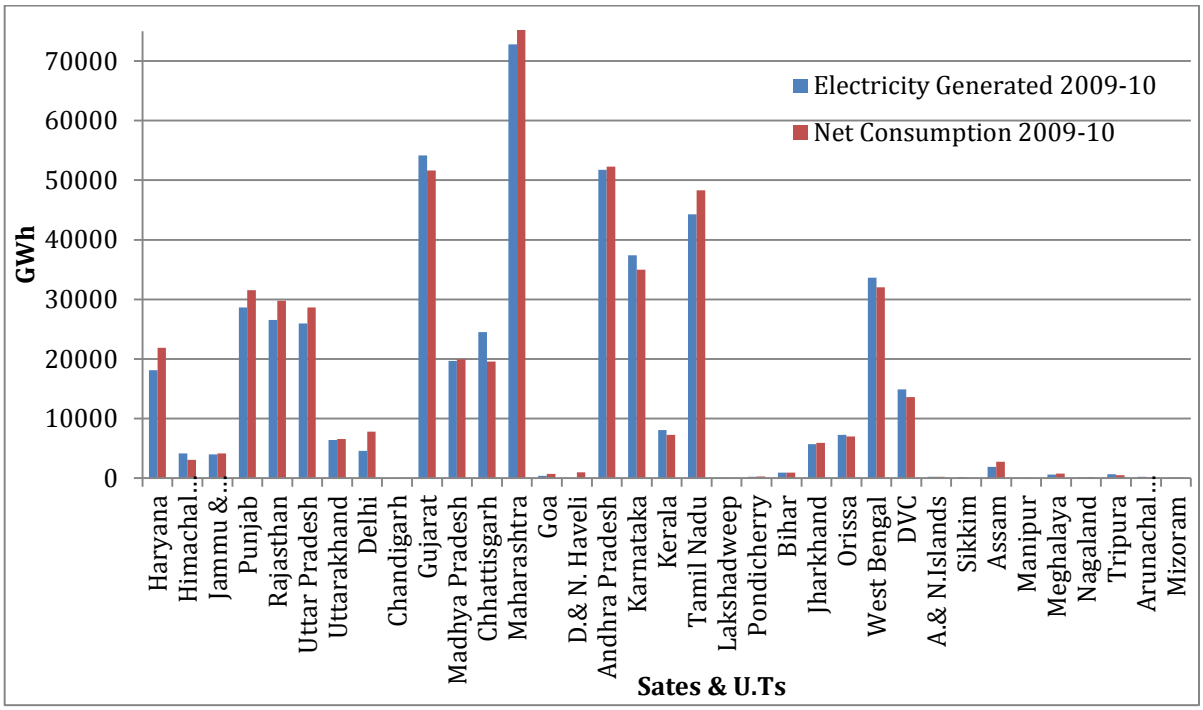
1.1 STATE OF THE POWER SECTOR IN INDIA (2009-10)

Though the total ex-bus energy availability increased by **8.0%** over the previous year and the peak met increased by **7.5%**, there were still significant shortages in the country both in terms of both energy and peaking availability as given below:

	Energy (MU)	Peak (MW)
Requirement	8,30,594	1,19,166
Availability	7,46,644	1,04,009
Shortage	83,950	15,157
% shortage of requirement	10.10%	12.70%

The energy requirement registered a growth of **6.9%** during the year against the projected growth of **8.2%** and Peak demand registered a growth of **8.5%** against the projected growth of **8.2%.**

1.2 State wise contribution in electricity generation and consumption



About 50% of states & union territories are not self sufficient in electricity generation and are dependent on others states to fulfill their requirements.

Maharashtra is highest generator and consumer of electricity with Gujarat, Andhra Pradesh and Tamil Nadu close behind. Chhattisgarh exports the largest amount of electricity at **4941 GWh** while Tamil Nadu imports **4046 GWh** which is the highest in the country.

2. Scope and Methodology

The data is sourced from CEA reports and calculations are done as outlined in the IPCC 2006 guidelines.

Calculation of Adjusted Electricity Generation Emission factor (kgCO2e/kWh)

$$\frac{(E_1 + E_2) - E_3}{T_1} = R_1$$

Where,

E_1 = Emission from fossil fuels used for electricity generation (kgCO2e)

E_2 = Emission from electricity imported from other states (kgCO2e)

E_3 = Emission from electricity exported to other states (kgCO2e)

T_1 = Total electricity consumed by state (kWh)

R_1 = Adjusted Electricity Generation Emission factor (kgCO2e/kWh)

- Fossil fuel electricity generation technologies include coal, thermal, Gas turbine generation and Diesel Generators.
- Emissions from renewable energy technologies are considered to be zero.

Calculation of AT&C Losses Emission Factor (kgCO2e/kWh)

$$\frac{(T_1 \times R_1 \times P_1)}{T_2} = R_2$$

Where,

T_1 = Total electricity generated by state (kWh)

T_2 = Total electricity consumed by state (kWh)

R_1 = Adjusted electricity generation emission factor of state (kgCO2e/kWh)

P_1 = % of AT&C losses in the state (AT&C loss percentage of total electricity generated in state)

R_2 = AT&C Loss Emission Factor (kgCO2e/kWh)

Calculation of End User Specific emission factor (kgCO2e/kWh)

$$(R_1 + R_2) = EF$$

Where,

R_1 = Adjusted electricity generation emission factor of state (kgCO2e/kWh)

R_2 = AT&C Loss Emission Factor of state (kgCO2e/kWh)

EF = End user specific emission factor (kgCO2e/kWh)

3. Results:

3.1 State wise Emission Factor of Electricity

	Total Electricity Generated (All Sources)[1]	AT&C Loss % (Excluding Aux. Power Consumption)[2]	Emission Factors (Generation based)	A) Emission Factor for End-User Consumption with adjusted Import & Export of Electricity	B) Emission Factors for AT&C Losses	Combined Emission Factor for End-User Consumption (A+B)
	GWH	GWH	(kgCO2e/kWh)	(kgCO2e/kWh)	(kgCO2e/kWh)	(kgCO2e/kWh)
All India	795176	25	**0.89**	**0.89**	**0.30**	**1.19**
South Grid	207995	19	0.90	0.90	0.35	1.25
NEWNE Grid	555418	28	0.85	0.85	0.19	1.04
State/U.T.'s						
Haryana	18105	31	0.87	0.91	0.37	1.27
Himachal Pradesh	4138	21	0.00	0.21	0.05	0.26
Jammu & Kashmir	3988	67	0.00	0.28	0.52	0.81
Punjab	28630	23	0.68	0.76	0.21	0.97
Rajasthan	26572	30	0.79	0.87	0.34	1.21
Uttar Pradesh	25936	33	1.05	1.11	0.50	1.61
Uttarakhand	6392	25	0.00	0.09	0.03	0.12
Delhi	4597	22	0.69	0.84	0.21	1.05
Chandigarh[3]	0	23	0.00	1.03	0.28	1.30
Central Sector (NR)	101894		0.66			
Northern Region (NR)	220251	30	0.70			
Gujarat	54129	23	0.73	0.81	0.21	1.02
Madhya Pradesh	19670	38	0.98	1.08	0.60	1.68
Chhattisgarh	24518	19	1.03	1.13	0.23	1.37

[1] Data Source : CEA – All India Electricity Statistics – General Review 2011
[2] Data Source : CEA – All India Electricity Statistics – General Review 2011
[3] Chandigarh is exporting more quantity than total generation so on the conservative principal assumed that one State whatever is importing within that it is consuming electricity embedded with higher emission.

Maharashtra	72807	25	0.88	0.97	0.29	1.26
Goa	398	17	0.40	0.60	0.11	0.71
D.& N. Haveli[4]	0	11	0.00	0.76	0.09	0.84
Daman & Diu	0	17	0.00	0.76	0.14	0.90
Central Sector (WR)	82952		0.76			
Western Region (WR)	254475	26	0.83			
Andhra Pradesh	51758	18	0.63	0.76	0.14	0.91
Karnataka	37385	19	0.49	0.59	0.11	0.70
Kerala	8090	20	0.07	0.11	**0.02**	0.13
Tamil Nadu	44259	18	0.82	0.95	0.18	1.13
Lakshadweep	29	12	1.01	1.20	0.13	1.33
Pondicherry	227	12	0.67	0.86	0.10	0.96
Central Sector (SR)	55460		0.96			
Southern Region (SR)	197208	19	0.72			
Bihar	915	44	1.12	1.23	**0.86**	**2.10**
Jharkhand	5687	22	**1.21**	**1.33**	0.34	1.68
Orissa	7287	37	0.51	0.58	0.31	0.88
West Bengal	33637	18	0.97	1.08	0.22	1.29
DVC	14879	20	1.02	1.13	0.25	1.38
A.& N.Islands	232	20	0.59	0.65	0.14	0.79
Sikkim[5]	164	39	0.00	0.66	0.38	1.04
Central Sector (ER)	51898		1.14			
Eastern Region (ER)	114699	27	1.03			
Assam	1883	33	0.63	0.84	0.37	1.21
Manipur	20	55	0.04	0.75	0.81	1.56
Meghalaya	589	39	0.00	0.26	0.15	0.42
Nagaland	99	57	0.00	0.64	0.77	1.41
Tripura	675	36	1.03	1.13	0.56	1.69
Arunachal Pradesh	234	48	0.00	**0.06**	0.05	**0.11**
Mizoram	103	54	0.01	0.32	0.33	0.65
Central Sector (NER)	4939		0.36			
North Eastern Region (NER)	8543	39	0.43			

The following results stand out from the above table:

1. Jharkhand has the highest emission factor for generation at **1.21 kgCO2e/kWh** and also the highest emission factor after adjusting for import and export of electricity which is **1.33 kgCo2e/kWh**

2. Bihar has the highest AT&C losses in the system due to which it has the highest emission factor for AT&C losses which is **0.86 kgCO2e/kWh.** This also results in it having the highest emission factor for end user consumption of electricity at **2.1 kgCO2e/kWh**.

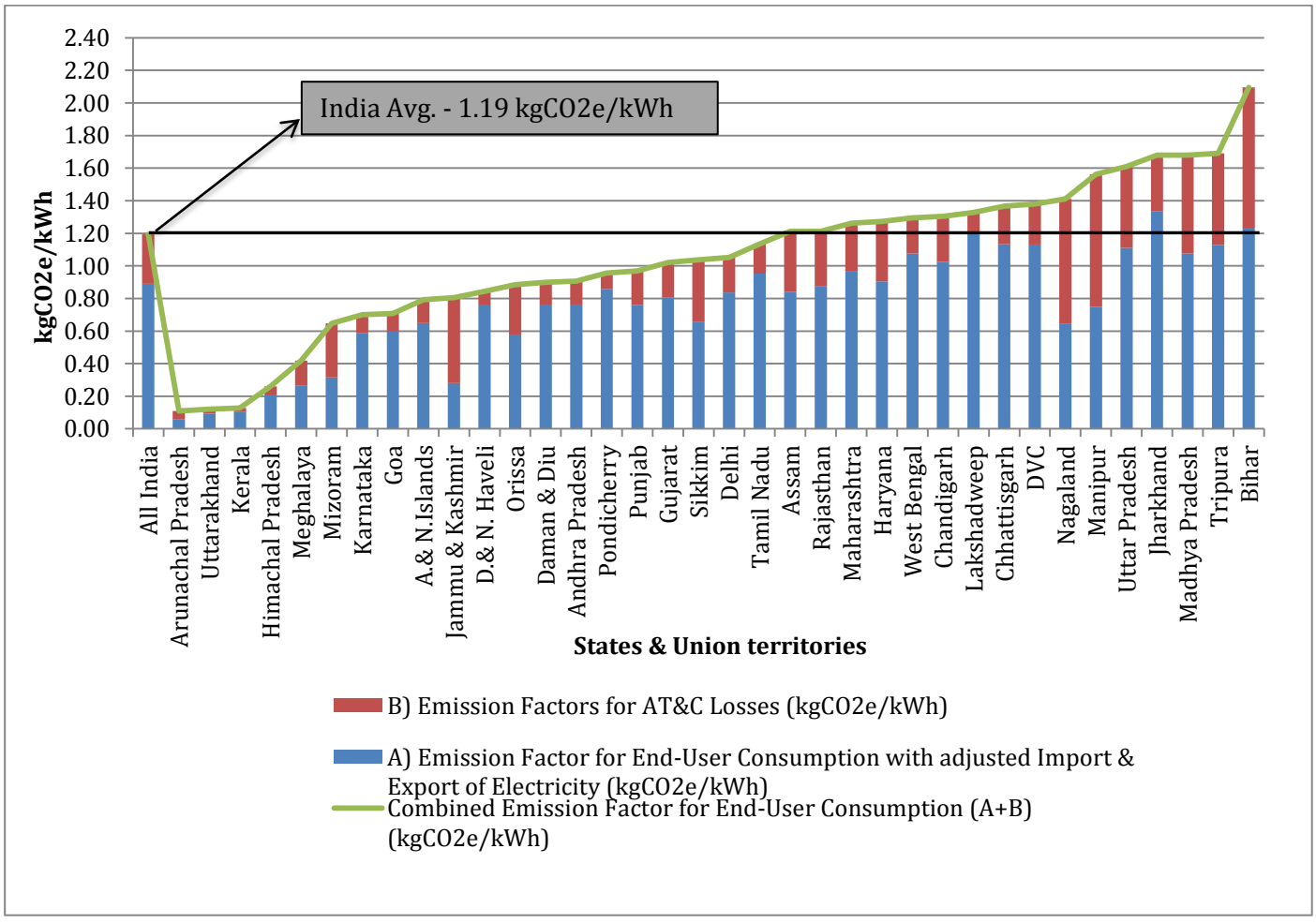
[4] Dadra & Nagar Haveli and Daman & Diu Electricity GHG EF (except AT&C Loss GHG EF) is same because it has been calculated on combined level due to non availability of quantity of exported and imported electricity.

[5] Sikkim is exporting more quantity than total generation so on the conservative principal assumed that one State whatever is importing within that it is consuming electricity embedded with higher emission.

3. The average India electricity generation emission factor is **0.89 kgCO2e/kWh** and average India AT&C loss emission factor is **0.30 kgCO2e/kWh**.

4. States that import electricity are liable for the corresponding proportion of emissions of each state from where electricity is imported. Hence some states like Sikkim, Assam, Manipur, Nagaland in particular appear to be "dirtier" i.e. their emission factors are quite high because they are importing electricity from states which have a high electricity generation emission factor.

3.2 State wise end user consumption emission factor of electricity

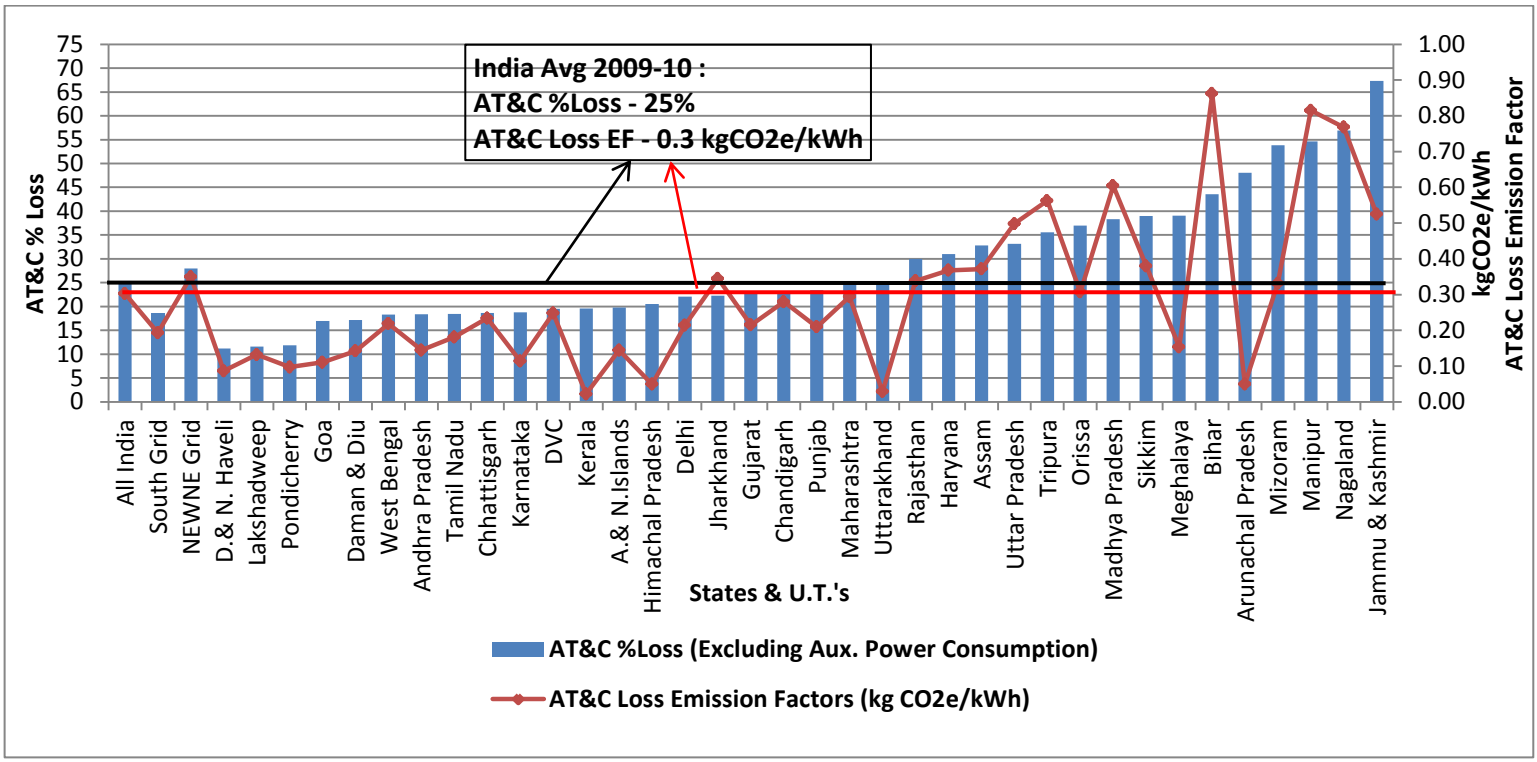


Graph 1: State wise end user electricity emission factor

In the above graph we can see almost 45% of states have an end user emission factor that is higher than the India avg. emission factor of electricity generation.

In many cases we can see that states have a low adjusted emission factor for generation but due to high AT&C losses their end user emission factor is higher than the India avg. emission factor. This point is illustrated in detail in the graph below.

3.3 State wise AT&C losses and emission factors for AT&C losses



Graph 2: State wise AT&C % losses and AT&C loss emission factors

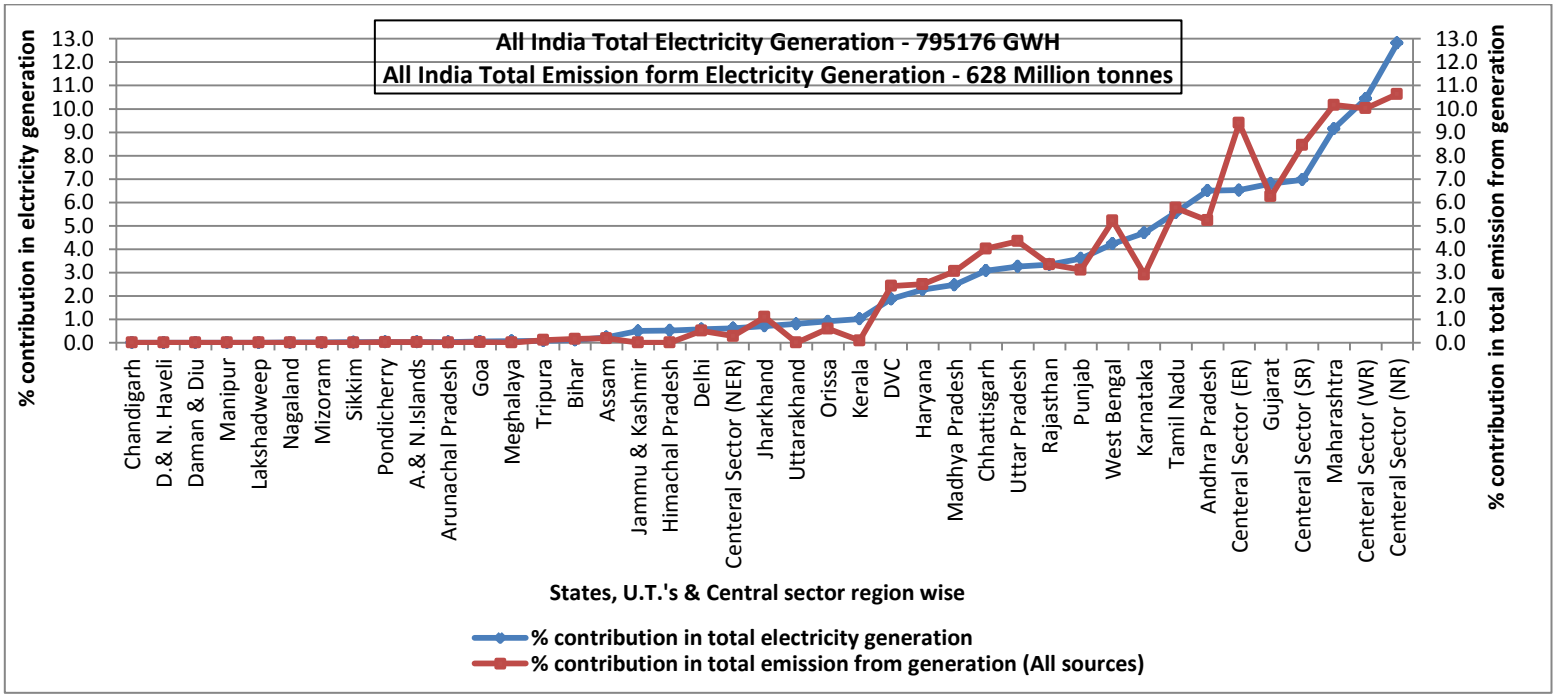
As shown above the India average AT&C % loss is 25%. Also there is a big variation in the % losses between the grids specifically such as the South grid and NEWNE grid.

Highest AT&C % loss of **67%** is recorded from Jammu & Kashmir and the lowest one recorded from D.&N. Haveli which is **11%**.

About **40%** states have higher AT&C system losses than the India average which points to a huge potential to save electricity with up gradation of technology and proper maintenance of transmission and distribution systems. It is also noticeable that states with difficult terrain such as hills and forests have higher AT&C losses than other states.

Another important fact visible in the graph above is that the AT&C loss emission factor is not only dependant on the quantum of losses but also on the source of electricity generation. Hence a state with low AT&C losses but "dirtier" sources of electricity generation could still have an AT&C emission factor higher than that of a state with higher losses but cleaner sources of generation. For e.g. Arunachal Pradesh has extremely high losses of about **47%** but since most of its electricity is generated through hydel power its AT&C factor is less than **0.1 kgCO2e/kWh**. Whereas Jharkhand has losses of only about **23%** but its AT&C emission factor is about **0.3 kgCO2e/kWh** since most of its electricity is generated from coal.

3.4 State wise contribution in electricity generation and emission from electricity generation



Graph 3: State wise % contribution in total electricity generation and % contribution in total emission from generation of electricity (all sources)

In the above graph we can see that a majority i.e. 23 states and UT's contribute less than 1% each to India's generation and emission stock. The majority generators are

Maharashtra, & Gujarat and they are responsible for **9.2%** and **6.8%** of generation stock and **10.2%** and **6.3%** of emissions respectively.

Karnataka also has the lowest percentage of emissions of **2.9%** with respect to it percentage of generation stock of **4.7%** while Uttar Pradesh has the highest percentage of emissions of **4.3%** over its percentage contribution to the generation stock at **3.3%**.

4. Conclusion

A majority of emissions from the power sector are due to usage of coal as a primary medium for electricity generation (68%). There is a large potential to reduce emissions through usage of better quality of coal, more efficient technologies as well as moving to cleaner technologies such as thermal, hydro, solar etc. But these scenarios depend on various factors such as cost, geographical location, availability of raw materials etc and hence are hard to predict.

	Gross Production 2009	AT&C Losses	AT&C % Loss	Contribution to Total Emission from AT&C Losses
	TWh	TWh	%	Million tonnes CO2e
World	20129.8	1688.3	8.4	
India	763.4	193.8	25.4	172
India with world avg. AT&C Loss Factor	763.4	64.1	8.4	57
		Potential Saving of Million Tonnes of CO2e		**115**

But as shown earlier, states with relatively clean generation technologies still have quite a poor end user emission factor due to major AT&C losses. This is a "low hanging fruit" opportunity for states to drastically improve their quality of electricity and emission factors. For e.g. if all states whose AT&C losses lie below the India avg. of 25% move up to atleast the average, an emission reduction of approximately **15 MTCO2e** is possible. In the best case scenario if all states improve their efficiency of AT&C to the world average of **8.4%** phenomenal savings of **115 MTCO2e** are possible which is a reduction of about **67%** of emissions due to AT&C losses. These steps can go a long way in helping India achieve its goal of 20-25% reduction in emissions over 2005 levels by 2020.

5. References

In addition to the data gathered in research, the report has been compiled from the following additional resources:

1. Data Source : CEA – All India Electricity Statistics – General Review 2011

2. IPCC Guidelines 2006

3. https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CDUQFjAB&url=http%3A%2F%2Fwww.cea.nic.in%2Farchives%2Fgod%2Flgbr%2F1011.pdf&ei=qd3IUISZC4ztrQft24HQDA&usg=AFQjCNE3TCnijwMufqRLyIqvzRt5ceuY0A&bvm=bv.1355272958,d.bmk

6. GLOSSARY

AT&C Loss	Aggregate Technical and commercial Losses
CEA	Central Electricity Authority
DVC	Damodar Valley Corporation
GWh	Giga Watt Hour (equivalent to 1 Million unit of Electrical Energy)
IPCC	Inter Governmental Panel on Climate Change
KWH	Kilo Watt Hour
MU	Million Units
MW	Mega Watt (equivalent to 1000 Kilo Watt)
NEWNE	North East West North Eastern
UT	Union Territory