Assessment of carbon footprint of Jaffna Town, Sri Lanka

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Abstract. Jaffna town is one of the emerging urban centers in Northern Sri Lanka which attract more people, resources and activities in the post war scenario. This study assesses the carbon footprint of the town. Cities play a key role to top up greenhouse gases into the atmosphere worldwide which lead to global warming and consequent climate change and related impacts. The carbon footprint of Jaffna town has not been assessed yet and the awareness of low carbon development is not common in the development domain which are essential to make decisions to carry out development consistent with Sustainable Development Goals. The purpose of the research to assess the gross carbon emission of Jaffna town and sectoral composition of the emission. The study shows that the city emits 312,096,821 Kg Co2e per day. More emission comes from domestic activities which account for 60% and second largest emission comes from transport sector. Nearly 60% of the commuters are using private vehicles that account for nearly 20% of the total emission. Among the domestic emission, light and ventilation consume more energy than other uses. Solid waste management also contributes to emit nearly 6 – 10% of the emission of the city. More houses consume relatively higher energy for light and ventilation because of the poor design of house that do not utilize the natural light and ventilation. The study suggest that the building design must adhere to the low carbon building designs which is not present in Jaffna. Appropriate building design that minimize the energy consumption need to formulated and implemented. Use of centralized air conditioning system in public building will minimize the energy consumption compared to distributed system. Integrated waste management system and sanitary land fill facilities will minimize the emission from solid waste disposal. Suitable urban design will encourage walking and cycling of residents and commuters. Deliberate planning of routes and facilities of public transport will promote the use of public transport between Jaffna and other suburban towns in the Northern Region.

1. Introduction
This research has assessed the level of carbon emission into the atmosphere from various activities in Jaffna town, Sri Lanka. Jaffna town is a first order city in the Northern Province of Sri Lanka and growing rapidly after the end of civil war. Though, Jaffna town is a smaller town center compare to the cities around the world, all urban areas depending on the size of the city and functions, they emit greenhouse gasses into the atmosphere. Based on the general principles of sources of green house gas emission, possible sources of emission were studied in this research. Data on transportation activities of residential population, retail and wholesale business activities, government and private institutions, energy use in residence, business places and institutions, goods and services consumed by residential people and institutions were collected using...
questionnaires and waste generated and disposed from the city were collected from statistical records of Jaffna Municipal Council. In each sector, per unit emission was calculated based on the survey data using carbon calculators and total emission of the city was calculated considering the total number of entities.

Jaffna town is located at the Northern most part of Sri Lanka, nearly 400 kms away from the capital city of Colombo. The administrative areas of the town cover nearly 20 square kilometers and actual urban areas have spread beyond the administrative boundary. Jaffna town is mostly serving the Jaffna Peninsula and the Northern Province.

2. Research Problem
Cities around the world account for 80% of the green house gas emission and each city in the world has stake in the total emission[1]. More than 70% of the energy consumed by cities in the world which are burned and emitted as greenhouse gases into the atmosphere[2]. Cities proportionately emit greenhouse gases, depending on the total population, urban form and functions. Number of people living in Jaffna town has been increasing rapidly during the last ten years. There are more than 100,000 people live in the city and nearly 65,000 people are commuting to the city daily. Number of automobiles used by the residents and commuters are increasing day by day. There are larger number of construction projects undertaken in various parts of the town. Land use and land cover changes are taking places at different scales in different walk of life of the city. More than 63% of the land use is allocated for residential activities. Residential areas consist of home garden with greeneries. There are 25238 housing units in the town area. Green land cover and natural environments are converted into unnatural and constructed surfaces. Since there are activities related to energy consumption and methane productions, Jaffna town also contributes to add carbon into the atmosphere which has been unaccounted in the past[3]. Every aspect of Jaffna Town add carbon into the atmosphere. They are land use conversion, waste disposal, increasing dependency on automobiles, waste water disposal, energy consumption at households, institutions and business places. Though the global Warming and climate change are global issues, created by local activities, mitigation requires local response to them by minimizing carbon emission from various activities locally. What is measured get managed is true in carbon emission as well. Therefore, the current condition of the emission from various activities of the town needs to be assessed in order to take decisions with respect to low emission urban design.

3. Objectives
This research has four objectives to;

- Assess the total carbon emission of Jaffna Town
- Assess sectoral contribution of carbon emission
- Assess per capita emission
- Formulate guidelines to control low carbon development in Jaffna Town

4. Research Design
This research has been conducted based on survey data and quantitative analysis to assess the total and sectoral carbon footprint of the town. The aim of the research is to assess the level of carbon emission and devise methods to create low carbon environment. It required to assess per activity emission and sectoral emission which are the fundamental level functional understanding necessary for planning a low carbon environment. The activities that emit carbon were mainly considered transport, energy, goods and services and solid waste. Questionnaire survey was conducted to collect data on activities that have the nature of carbon emission. The questionnaire consisted of open ended and closed questions under four sections. The transport sector consisted questions of what type of transport the people live in the city use, type of transport used by the government and private institutions, used by retail and wholesale business people, distanced travelled, type of vehicles used, capacity of motorbikes, what type of vehicles used for goods transport etc.
Questions in energy sector consisted the following questions electricity use of households, private and government institutions, retail and whole sale business places, type of energy used, industries in the town, utility equipment used such as refrigerators, washing machines, cookers, bulbs, fans, iron boxes, air conditioners, electric water pumps. Primary data was collected from questionnaire survey and summarized and analyzed using SPSS v25. Total of 120 questionnaires were filled and stratified random sampling method was adopted to select the samples. The number of questionnaires surveyed in each sector are as follows; 40 questionnaires for householders, 20 for retail business establishments. 20 for wholesale establishments, 20 for government institutions and 20 for private institutions. The carbon emission from each activity was calculated based on the data collected from questionnaire survey and using carbon calculator software[4] available online and standalone. Per head emission in each sector was calculated and was multiplied by number of people or activity or institutions in the town to get total emission.

5. Results and Discussion

The performance of each sector that contribute to carbon emission has been taken into account and assessment were carried out. Main functions and sectors that are liable for carbon emission have been studied and data were collected. In this section, sectoral contribution such as transport, energy use, goods and services consumption, waste generation and disposal have been assessed and emission from those activities were calculated. Further, functionalities also have been assessed and their carbon emission were worked out.

5.1 Activities based Carbon Emission

5.1.1 Transport in Jaffna Town Assessing the carbon footprint of a town, assessment of transport sector emission is crucial. Transport sector contributes to the emission substantially. In this research, transport uses in different sectors were considered and data on the distance travelled collected. Each respondent was asked the distance travelled per day and the mode of transport they used. The data were summarized and analyzed. The table 1 shows the distance travelled and the mode of transport used in different sectors.

Table 1: Distanced Travelled Per Day (Kms) By Various entities in the Town

| Transport Mode | Total Travelled Distance (Km) |
|----------------|-----------------------------|
| Bicycle        | 315                         |
| Motor Bike     | 10,175                      |
| Lorry          | 3,417                       |
| Private Bus    | 3,296                       |
| Public Bus     | 1,716                       |
| Car/Auto       | 3,799                       |
| Van            | 2,769                       |
| Land Master    | 27                          |
| **Total**      | **22,697**                  |

Source: Questionnaire Survey, 2014

5.1.2 Motorbikes Use and Capacities In Jaffna, most people use motorbikes, which have different capacities, for transport needs. The capacity of those motorbikes used by different users in various places was also considered to assess the carbon emission. More journeys made using motorbikes by people in government and private institutions. Most motorbikes are in the 100 cc category.
Table 2: Distance Travelled Using Motorbike Types in Business Places, Institutions and Settlements (Km)

| MB Capacity | Business Places |
|-------------|-----------------|
| 90 cc       | 30              |
| 100 cc      | 7099            |
| 125 cc      | 2361            |
| 135 cc      | 267             |
| 150 cc      | 195             |
| 180 cc      | 315             |
| 200 cc      | 06              |
| **Total**   | **10273**       |

*Source: Questionnaire Survey, 2014*

5.1.3 Usage of Electrical Equipment

Emission from energy use also has been studied by assessing the number of electrical equipment used and electricity units consumed by different sectors. The total energy consumed from different functions and sectors were assessed from secondary data on electricity unit consumption. The following table shows the electrical equipment used in different sectors.

Table 3: Electrical Equipment Used in Business Places, Government and Private Institutions, and Settlements

| Electrical Equipment | Business Places | Govt. Institutions | Private Institutions | Dwelling Units | Total |
|----------------------|-----------------|--------------------|----------------------|----------------|-------|
| Bulb                 | 451             | 26,260             | 119                  | 608            | 27,506|
| Fan                  | 105             | 13,760             | 1,246                | 164            | 13,879|
| Computer             | 14              | 340                | 241                  | 51             | 581   |
| Air Conditioner      | 08              | 312                | 183                  | -              | 495   |
| Fridge               | 04              | -                  | 15                   | 25             | 19    |
| Water Pump           | 04              | 15                 | 06                   | 43             | 68    |
| Printers             | 04              | 156                | 14                   | -              | 174   |
| Cookers              | -               | -                  | -                    | 24             | 24    |
| Washing              | -               | -                  | -                    | 12             | 12    |
| Iron Boxes           | -               | -                  | -                    | 40             | 40    |
| Industrial Equipment | -               | -                  | -                    | 04             | 04    |

*Source: Questionnaire Survey, 2014*

5.1.4 Electricity Consumption

Electricity use contributes to carbon emission when they are generated from fossil fuel-based sources. In Sri Lanka, more than 60% of the electricity is generated from thermal power. Data on energy usage, which was represented by electricity units utilized by every separate entity, were collected from each sector. Almost all people use electricity for light, ventilation and operating household equipment in the town area. The following table 4 shows the amount of electricity consumed per day in sectors.
Table 4: Electricity Consumption in Sectors

| Sector                                  | Electricity Units Used |
|-----------------------------------------|------------------------|
| Retail and Wholesale Business Places    | 3,461                  |
| Government and Private Institutions     | 14,309,904             |
| Settlements                             | 5,046                  |
| **Total**                               | **14,318,466**         |

*Source: Questionnaire Survey, 2014*

5.1.5 Consumption of Goods and Services

Consumption of goods and services also contribute to emit carbon since they are manufactured and processed using fossil fuel energy. Food and stationery were accounted for the estimates of carbon emission. Data on goods and Services consumed by different sectors in Jaffna Town were collected. The amount of papers consumed by users in different sectors were considered in calculating the carbon emission. The following table 5 shows the amount of papers consumed by sectors.

Table 5: Stationery Consumption by Sectors

| Sector                                  | Paper Consumed in Kg |
|-----------------------------------------|----------------------|
| Retail and Wholesale Business Places    | 65                   |
| Government and Private Institutions     | 388                  |
| Settlements                             | 13.5                 |
| **Total**                               | **466.5**            |

*Source: Questionnaire Survey, 2014*

5.1.6 Disposal of Solid Waste in Jaffna Town

Jaffna urban area disposes 30.2 metric tons of wastes from various activities, settlements, markets, hospital, commercial and business activities. The entire wastes are disposed in open dump site in Kallundai which lies 2 kilometers away from the town at the North Western direction. The dumping area inundates during rainy season from October to February. Open dumping of solid waste liable for emission of methane by anaerobic process and carbon dioxide by burning activities.

5.2 Carbon Emission from Activities and Sectors

The carbon emission for each activity in the town was calculated on the basis of unit emission using carbon footprint calculators. Carbon emission from transport, energy use, stationery consumption and waste disposal were calculated for the data collected using questionnaire survey and secondary sources.

5.2.1 Emission from Transports Activities

If looked at the carbon emission due to the transport activities of retail and wholesale business in the town, one business place emits 31.425 Kg of carbon per day and there are 8326 business entities in the town. All business entities emit total of 261,644 Kg of carbon per day.

The analysis shows that the transport activities of government and private institutions as follows; carbon emission of one institution is 98.34 Kg and there are 783 institutions in the town which all together emit 77,003 Kg of carbon per day.

Settlements due to transport activities emit carbon in the following manner. One dwelling unit emits 10.81 Kg of carbon per day. There are total of 25,238 dwelling units in the town area which emit 273,077 Kg of carbon per day. The table 6 below shows the distance travelled and total carbon emitted by transport activities in all three sectors in the town.
Table 6: Carbon Foot Print of Transport Activities of Business Places, Institutions, Settlements

| Transport Mode | Distanced Travelled (Kms) | Carbon Foot Print (Kg) |
|----------------|---------------------------|------------------------|
| Bicycle        | 315                       | 00                     |
| Motorbike      | 10,175                    | 1,240                  |
| Car / Auto     | 3,799                     | 680                    |
| Lorry          | 3,417                     | 1,168.86               |
| Van/ Ambulance | 2,769                     | 703.82                 |
| Land Master    | 27                        | 2                      |
| Private Bus    | 3,296                     | 1,252                  |
| Public Bus     | 1,716                     | 587                    |
| **Total**      | **22,697**                | **5,633.68**           |

*Source: Questionnaire Survey, 2014*

Considering the sectoral assessment of transport activities, carbon emission has been calculated. This has been done by summing up the sectoral transport performance. The following table 7 shows the total carbon emission from transport in three sectors

Table 7: Carbon Emission from Transport Activities of Business Places, Institutions and Settlements

| Sectors                              | Carbon Emission (KgCo2e) |
|--------------------------------------|--------------------------|
| Retail and Wholesale Business Places | 262,644.55              |
| Government and Private Institutions  | 77,003.15               |
| Settlements                          | 273,077                  |
| **Total**                            | **611,724.7**            |

*Source: Questionnaire Survey, 2014*

5.2.2 Emission from Energy Usage. When people consume energy, it contributes to add carbon into the atmosphere. In this research, Carbon Foot Print from energy sources used in various sectors in the town was calculated. The following table shows the sectoral emission from energy use.

Table 8: Sectoral Carbon Emission from Energy Use (Samples)

| Sector                    | Monthly Energy Use (Units) | Daily Energy Use (Units) | Carbon Emission per day (KgCu2e) |
|---------------------------|----------------------------|--------------------------|----------------------------------|
| Retail and Wholesale Business | 3,461                     | 115.36                   | 120.44                           |
| Government and Private Institutions | 14,309,909                | 476,996.96               | 497,984.88                       |
| Settlements               | 5,096                      | 169.86                   | 177.34                           |
| **Total**                 | **498,282.66**             |                          |                                  |

*Source: Questionnaire Survey, 2014*

Total carbon emitted from energy per month is 14,948,480 KgCo2e. The emission per day was calculated dividing the monthly emission by 30 which is 498,282.99 KgCo2e.
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Table 9: Total Sectoral Carbon Emission from Energy Use Per Day

| Sector                     | Emission per Entity (KgCo2e) | No of Entities | Total Emission (KgCo2e) |
|----------------------------|-------------------------------|----------------|-------------------------|
| Retail and Wholesale Business Places | 3.011                        | 8326           | 25,069.58               |
| Government and Private Institutions | 12,449.62                    | 783            | 9,748,052.46           |
| Settlements                | 4.43                         | 25,238         | 111,804.34              |
| **Total**                  |                               |                | **9,884,926.38**       |

Source: Questionnaire Survey, 2014

5.2.3 Emission from Consumption of Goods and Services. The following table shows the carbon emission from Consumption of Stationery particularly papers. Manufacturing of papers consume energy that leads to carbon emission. Based on the total paper consumed by various entities, emission per kg of papers and total emission were calculated. Table 9 shows the emission from consumption of papers.

Table 10: Carbon Emission from Stationery Use in Sectors

| Sector                      | Emission                          |
|-----------------------------|-----------------------------------|
| Retail and Wholesale Business Places | 18,759,310.6                   |
| Government and Private Institutions | 10,530,880                  |
| Settlements                 | 11,808,860                        |
| **Total**                   | **41,099,050**                   |

Source: Questionnaire Survey, 2014

Production, processing, transporting of foot stuff also involve energy consumption and carbon emission. Based on the amount of food consumed by an individual, Carbon Foot Print one kg of Food has been calculated. Table 10 shows the amount of emission from consumption of food.

Table 11: Carbon Foot Print of Consumption of Food Per Day

| Carbon Foot Print Per Head / Day (KgCo2e) | Total Population in the Town | Total Carbon Emission Per Day (KgCo2e) |
|-----------------------------------------|-----------------------------|----------------------------------------|
| 2740                                    | 98,647                      | 247,364,460                            |

Source: Questionnaire Survey, 2014

5.2.4 Emission from Solid Waste Disposal. Emission per metric ton of waste has been calculated using carbon calculator. Table 11 shows the amount of emission from the waste produced in the town area.

Table 12: Carbon Foot Print of Solid Waste Per Day

| Carbon Foot Print Per Kg of Solid Waste (KgCo2e) | Total Solid Waste Per Day (Metric Ton) | Total Carbon Emission Per Day (KgCo2e) |
|-------------------------------------------------|----------------------------------------|----------------------------------------|
| 441.2                                           | 30                                      | 13,236,669                             |

Source: Questionnaire Survey, 2014
5.2.5 Sectoral Carbon Emission. Total emission from various sectors have been calculated summing up the sectoral emissions. The following table 12 shows the sectoral emission. In considering the sectoral emission, goods and services contributes more.

| Sector                  | Emission          | %   |
|-------------------------|-------------------|-----|
| Transport               | 611,724           | 0.2 |
| Energy/ Power           | 9,884,926.38      | 3.59|
| Goods and Services      | 251,474,411       | 91  |
| Solid Waste             | 13,236,660        | 4.8 |
| **Total**               | **275,207,722.01**| 100 |

*Source: Questionnaire Survey, 2014*

5.2.6 Carbon Emission from Functions
Carbon Foot Print from Different Functions have been calculated for the Town considering the data collected and analyzed for different functions in the town. Table 13 shows the functional type emission. Higher amount of carbon emitted from goods and services which is 91%.

| Sector                              | Emission (KgCo2e) | %   |
|-------------------------------------|-------------------|-----|
| Business                            | 19,046,024.73     | 6.5 |
| Government and Private Institutions | 20,355,935.66     | 6.5 |
| Settlements                         | 259,458,201       | 83.1|
| Solid Waste                         | 13,236,660        | 4.2 |
| **Total**                           | **312,096,821**   | 100 |

*Source: Questionnaire Survey, 2014*

In considering the functionality-based emission, larger amount of carbon is emitted from settlements which is 83.1 percent. Per capita carbon emission has been calculated based on the data and analysis carried out for the sectoral and functional activities of the town. The per capital emission is 718.66 KgCo2e per day.

6. Mitigation Measures for Low Carbon Environment
Since most people use private vehicles, promoting non motorable and public transport required to be promoted in order to minimize the emission from transport sector. Currently the public transport is not efficient and attractive therefore; people prefer to use private transport. Making public transport accessible and more comfortable is important to reduce private vehicles. Walking and cycling could be promoted among residents and commuters, if facilities and conditions for cycling and walking are provided. Arterial roads, A9 road, Point Pedro road, Palaly road, KKS road, Manipay road and Karainagar roads are mostly used by residents and commuters. Improving internal roads also will reduce the strain on the major roads. Most roads in Jaffna town are narrow and do not have right of way. Land acquisition depending on the grade of the road need to be undertaken in order to provide space for the provision of cycling and walking[3].

The designs of residential and public buildings are not energy efficient and consume substantial amount of energy and emitting carbon into the atmosphere[5]. Green Building Standards similar to LEEDs are adopted in Sri Lanka but those standards are not mandatory now. Making the Standards of Green Building Council are mandatory for all buildings including residential buildings, building designs would be more
Energy efficient[6]. Energy efficient design must be incorporated into the built environment that will utilize natural light and ventilation. Most of the residential buildings are owner designed and did not consider the elements of energy efficiency. Awareness about the importance of building design and energy efficiency will encourage people to seek the assistance of architects in designing the buildings. Production and use of renewable energy are not adopted in Jaffna town now. Less awareness and poor economic conditions prevent people from installing and using non-renewable sources such as solar photovoltaic and wind power generation.

There are many ways to reduce the emission from solid waste disposal in Jaffna Town. At the moment, recycling, reuse, composting of wastes are not effectively adopted[7]. Most wastes end up into dumping site unsegregated. People also do not have the habit of any of these good practices. Awareness among community members on reduction, reuse, recycle and composting will minimize the waste coming into the waste stream from the city. Sanitary landfill site for the final non-degradable waste will minimize the emission of methane and other toxic and greenhouse gases. Promotion of urban agriculture also will absorb substantial amount of organic waste and contribute to minimize the waste volume.

In conventional methods of business, activities consume more papers. Jaffna town has not adopted the digital technologies for main activities. Use of digital technologies and electronic communication will minimize the usage of papers in various places.

Water purification, water pumping and distribution consume energy. Rainwater harvesting, wastewater reuse and recycle are not practiced in Jaffna. Rainwater harvesting and waste water reuse will reduce water demand. Planning and building regulations to promote rainwater harvesting and wastewater recycling and reuse need to be formulated and adopted for Jaffna town. Adopting water efficient fixtures will minimize the water usage and reduce demand for supplied water.

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