

Chapter 1

Green Building, Energy Efficiency, Carbon and Ecological Footprinting (CF and EF), and Life Style Solutions (LSS)

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Abstract Ultimate solutions to climate change problems lie in regulating and controlling the three key sectors: production, consumption, and lifestyle. In fact, the third one automatically takes care of the first two because our production and consumption patterns and trends depend directly on our lifestyles. This boils down to the fact that key to climate change mitigation lies in our lifestyles. Food, clothing, and shelter are our primary requirements, and they all contribute significantly to increasing concentrations of greenhouse gases (GHGs) and ultimately to climate change problem. This chapter illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor in the residential sector. Subsequently, the chapter also shows what kind of researches need to be pursued in various educational and research institutions so as to gradually make every citizen of the society environmentally aware and responsible. In short, the presentation discusses and recommends the kind of activities which need regular pursuance, refinement, modification, and application in regard to evolving site-specific, region-specific, and ecosystem-specific environmental management plans that are aimed at combating the climate-regulated environmental crisis which is unfolding before us every day with a newer dimension.

Keywords Carbon footprint • Ecological footprint • Life style solutions • Climate change

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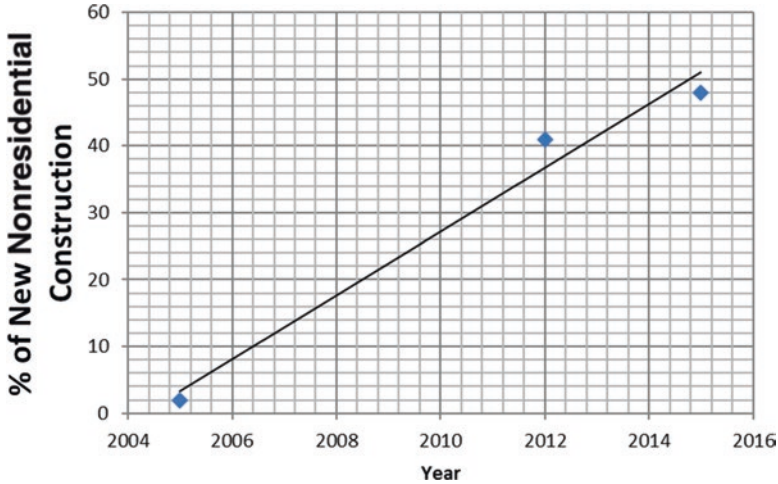


Fig. 1.1 Construction trend

1 Introduction

Buildings, in particular, have a significant contribution to make in terms of environmental impact as they are strongly dependent on highly energy-intensive materials like cement and steel. According to some estimates, they contribute to about 43% of the world's GHG-emissions (http://www.narucmeetings.org/Presentations/2009_Weston_Carbon.pdf). Also, it is worth noting that the waste from the construction material accounts for roughly 40% of landfill materials. Moreover, it is estimated that in the USA this year about 40–48% construction would be green. In economic terms, this opportunity is worth \$120–145 billion (<http://www.usgbc.org/articles/green-building-facts>). This trend over last one decade can be seen clearly in Fig. 1.1.

“Green building” or “sustainable building” essentially aims at increasing the efficiency of energy, water, and material consumption, while simultaneously reducing the adverse impacts on ecosystem and human health. This necessitates appropriate and better design for the building construction, operation, maintenance, and waste disposal. In short, green buildings reduce the overall negative impact on the environment by way of:

- Efficiently using energy, water, and other material resources
- Protecting and improving occupants' health and productivity
- Reducing waste and pollution generation and load

Ultimate solutions to climate change problems (Adger et al. 2005) lie in regulating and controlling the three key sectors: production, consumption, and lifestyle. In fact, the third one automatically takes care of the first two because our production and consumption patterns and trends depend directly on our lifestyles. This boils down to the fact that key to climate change mitigation lies in our lifestyles. Food, clothing, and

shelter are our primary requirements, and they all contribute significantly to increasing concentrations of greenhouse gases (GHGs) (USEPA 2005; Pandey et al. 1997) and ultimately to climate change problem.

This chapter illustrates some model development exercises based on realistic and relevant parameters, which are easy to measure and monitor in the residential sector. Subsequently, the chapter also shows what kind of researches need to be pursued in various educational and research institutions so as to gradually make every citizen of the society environmentally aware and responsible.

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2 Carbon Footprinting (CF) and Ecological Footprinting (EF)

Carbon footprinting (CF) and ecological footprinting (EF) (<http://www.ecologicalfootprint.com>; Rees and Wackernagel 1996, 1999; Mishra et al. 2008) are some of the recent environmental impact assessment tools, which not only help in understanding and quantifying impacts due to various activities like solid waste disposal, wastewater treatment, air pollution control etc. but also help in evolving appropriate cost-effective environmental management plans. Awareness has now significantly increased in respect of greenhouse gases (GHGs), global warming, climate change, and carbon footprints (CFs). Institutions like US Environmental Protection Agency (USEPA) and Water Utility Climate Alliance are already working vigorously in this direction. CO₂ (carbon dioxide), CH₄ (methane), N₂O (nitrous oxide), and fluorinated gases such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are the main GHGs, which contribute significantly to total CF. These GHGs have widely different global warming potentials according to the Intergovernmental Panel on Climate Change (IPCC 2006).

Activities that lead to GHG-emissions are said to be *carbon-positive*, while those which remove GHGs from the environment are known as *carbon-negative* or carbon-sinks. When GHG-emissions equal GHG-assimilation or absorption, the activities are known as *carbon-neutral*.

GHG-emissions can be of the following kinds:

- Direct
- Indirect
- Operational
- Embodied emissions

Combustion of fossil fuels, vehicular emission, and *methane emission from wetlands* come under the category of direct emissions. Indirect emissions include electricity

use/purchase, transportation of people, goods, material (chemical), and waste. Operational and embodied emissions are also used alternatively in place of direct and indirect emissions, respectively.

3 CF (Carbon Footprint):Calculators

In developed countries like America, where consumers are directly responsible for about 40% of GHG-emissions, CF-calculators are very frequently being used for estimating their GHG (CO₂-e) emissions. There are mainly two lifestyle components which are responsible for citizen's GHG-emissions: household activities and transportation.

However, not all CF-calculators give same or similar results. The differences amongst them could be as high as five to six million MT per year per individual. Some of the most popular CF-calculators can be listed as follows:

- American Forests (<http://www.americanforests.org/resources/ccc/>)
- Be Green (<http://www.greennow.com/>)
- BEF (Bonneville Environmental Foundation) (https://www.greentagsusa.org/GreenTags/calculator_intro.cfm)
- Carbon Counter.org (<http://www.carboncounter.org>)
- Chuck Wright (<http://www.chuck.wright.com/calculators/carbon.html>)
- Clear Water (<http://www.clearwater.org/carbon.html>)
- The Conservation Fund (<http://www.conservationfund.org/gozeroFund>)
- EPA (http://www.epa.gov/climatechange/emissions/ind_calculator.html)
- Safe Climate (<http://www.safeclimate.net/calculator/>)
- TerraPass (<http://www.terrapass.com/>)

Generally, the kind of inputs these CF-calculators require can be summarized as follows:

- Electricity/energy/oil/natural gas/propane/kerosene/wood consumption and related emission factors
- Waste generation and related emission factors
- Number of individuals/institutions/activities (as the case may be)
- Distance covered in transportation (flight/rail/road) and related emission factors
- Number of vehicles and their emission factors
- Use of air conditioners and their emission factors

And, the variations in CF-results are normally attributed to the following factors:

- Methodologies
- Individual behavioral features
- Conversion and emission factors
- Lack of transparency

The greatest uncertainty, however, is associated with emission (conversion) factors. Most of the calculators do not display or explicitly explain the methodologies behind these factors. As a result, they have used significantly different emission factors. These variations cannot be ignored in view of the fact that ultimately these calculators are supposed to influence and guide the citizens and policy makers for taking appropriate pollution (carbon) reduction measures and strategies.

Notwithstanding the uncertainty in their emission-estimates, these calculators do, however, generate awareness amongst common masses about environmental protection and conservation. This way they not only enhance their acceptability, but also become amenable to public understanding.

4 Ecological Footprint

The **ecological footprint** (EF) [<http://www.ecologicalfootprint.com/>] is a broad measure of resource use which highlights the areas where consumption is exceeding environmental limits. It mainly depends on the following parameters, which can be selected according to the options indicated before them (<http://steppingforward.org.uk/calc/>) (Table 1.1):

5 GHG-Emission from Transportation Sector

There are mainly three variables on which the GHG-emission from transportation is dependent: distance travelled in a given time period, the vehicle-specific fuel efficiency, and the presence/absence of air conditioner in the vehicle. In transportation sector, the differences in emissions could accrue mainly because of the differences in vehicle-specific emission factors chosen by different CF-calculators. For instance, Be Green's emission factor (Padgett et al. 2008) for air travel is 0.15 kg/km, whereas the factor used by BEF is 4.0 kg/km of CO₂-equivalent. Some CF-calculators like American Forests (AF) include emissions from even motorcycles, taxis, rail, buses, etc.

6 Residential Emissions

Residential emissions depend essentially on the following factors:

- Electricity consumption
- Household fuel use
- Solid waste disposal

Households are normally divided into three categories: single-family home, town-home, and apartments. The energy to CO₂-eq. Conversion factors vary from

Table 1.1 Parameters for assessing ecological footprint

S. no.	Parameters	Available options
1.	Travelling (transport)	<ul style="list-style-type: none"> • Car (average use) • Car (heavy use) • Car (light use) • Bus/train • Motorbike • Walking/cycling
2.	Living space (residential)	<ul style="list-style-type: none"> • Large house • Medium-sized house • Small house • Flat/apartment • Zero emission development zone
3.	Sharing of apartment (lifestyle)	<ul style="list-style-type: none"> • No other person • With one other person • With two other person • With three other person • With four other person • With five other person • With six other person • With more than six other person
4.	Heating/cooling bills (energy/electricity consumption)	<ul style="list-style-type: none"> • Low • Normal • High
5.	Use of electricity (type)	<ul style="list-style-type: none"> • Renewable • Nonrenewable
6.	Energy conservation measures	<ul style="list-style-type: none"> • Adequate • Not adequate
7.	Food habits	<ul style="list-style-type: none"> • Regular meat eater • Occasional meat eater • Heavy meat eater • Vegetarian
8.	Food imports/exports	<ul style="list-style-type: none"> • Locally produced food • Food items imported from different states • Food items imported from neighboring countries • Food items imported from distant countries
9.	Waste generation	<ul style="list-style-type: none"> • Average • Below average • Above average

(continued)

Table 1.1 (continued)

S. no.	Parameters	Available options
10.	Type of waste	<ul style="list-style-type: none"> • Recyclable • Nonrecyclable

0.25 (kg CO₂-e/kWh) used by clear water to 0.90 (kg CO₂-e/kWh) used by Chuck Wright. Bonneville Environmental Foundation (BEF) includes even transmission losses, while calculating their emission (conversion) factor [0.63 (kg CO₂-e/kWh)]. Some calculators like TerraPass have used monthly (temporal) variations too.

As far as emission factors for natural gas, fuel oil, and propane are concerned, there are large variations. For natural gas, the highest conversion factor is used by Safe Climate, which is about 1.33 times higher than the factor used by Clear Water (the lowest emission factor for natural gas). For fuel oil, Safe Climate uses the highest emission factor, which is approximately 1.36 times higher than the value used by Clear Water. Clear Water uses the lowest emission factor for fuel oil also. For propane, American Forests (AF) uses the lowest emission factor and Clear Water (CW) uses the highest emission factor (which is 7.1 times higher than that of AF) (<https://www.greenbiz.com/sites/.../EIARVol28Issue2-3pgs106-115.pdf>).

7 Climate Change and Green Buildings

According to an American estimate, energy use in commercial buildings accounts for 17% of US-GHG emission (<http://www3.epa.gov/climatechange/ghgemissions/sources/electricity.html>). Buildings have significant environmental impacts as they utilize and consume sizable amounts of natural resources like forest and mining products iron, steel, cement, limestones, water, etc. over their entire life cycle. This adds to further depletion of natural resources, which already are under serious threat due to excessive industrialization and commercialization. Therefore, while designing a green building, one has to keep in mind that this kind of resource depletion and the consequent environmental impacts are minimized.

Enhancing energy efficiency and reducing consumption at every step are the core issues while adopting appropriate mitigation approaches aimed at combating various kinds of environmental impacts. In other words, the same thing can be looked at as “bringing in lifestyle changes.” It gives rise to the need for innovative model development exercises aimed at delineating appropriate “environmental management plans” based on those parameters for which data can be easily collected in the residential complexes.

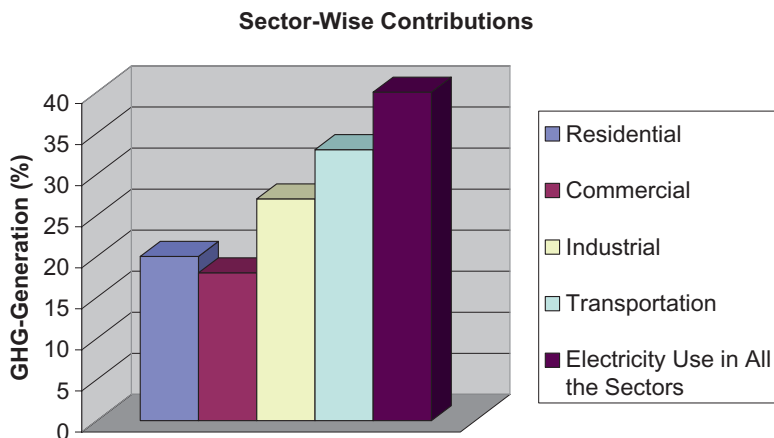


Fig. 1.2 Sector-wise CO₂-emissions

8 Models Representing Temporal Trends and Interdependence of CF and EF

Figure 1.2 provides the percentage contribution from various sectors (industrial, commercial, residential, and transportation) towards GHG-generation. In the same diagram is also shown the summed-up contribution from all these sectors (<http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html#emissions>).

When we look at the temporal trend of carbon footprint [Fig. 1.3], we find that its gradient, which was less than 25 (million metric tons of carbon/year) during 1900–1940 had a steep rise (gradient of 116 million metric tons of carbon/year) during 1940–2000, i.e., during the period of industrialization. Under the circumstances, it can be safely concluded that the intensity of material consumption had increased almost fourfold—thereby raising concerns regarding sustainability of the conventional development-framework (http://petrolog.typepad.com/climate_change/2010/01/cumulative-emissions-of-co2.html).

Global ecological footprint (Fig. 1.4) has also almost the similar trend during the same period, its gradients being 0.007 and 0.013 (Number of Earths per year) during the periods 1900–1940 and 1940–2000, respectively. (Figures 1.3 and 1.4 suggest that while during 1940–2000, there was a fourfold increase in carbon dioxide emissions (measured as carbon footprint (CF)), the overall impact on the environment (measured in terms of global ecological footprint (EF) was only twofold). When we tried to study the correlation (www.footprintnetwork.org) between EF and CF (Fig. 1.5), we found that its best representation ($R^2 = 0.944$) is through the equation $CF = 2540.5(EF)^2 + 3817.4(EF) - 77.797$ ($R^2 = 0.944$). Subsequently, we had also analyzed the per capita CF and EF values and studied their correlations (Fig. 1.6). These per capita correlations could be best represented in the form of $CF = 2.6855e^{0.2399(EF)}$ ($R^2 = 0.9186$).

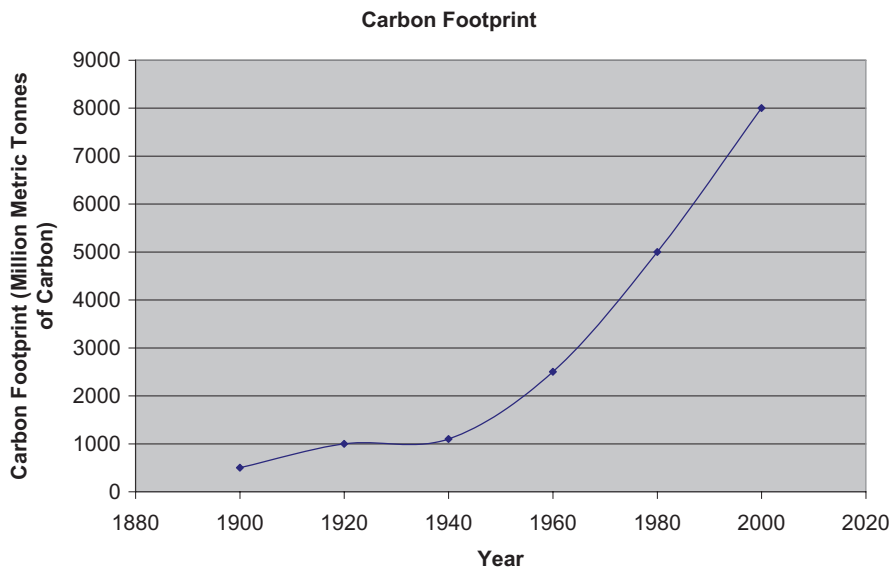


Fig. 1.3 Carbon footprint—temporal trend

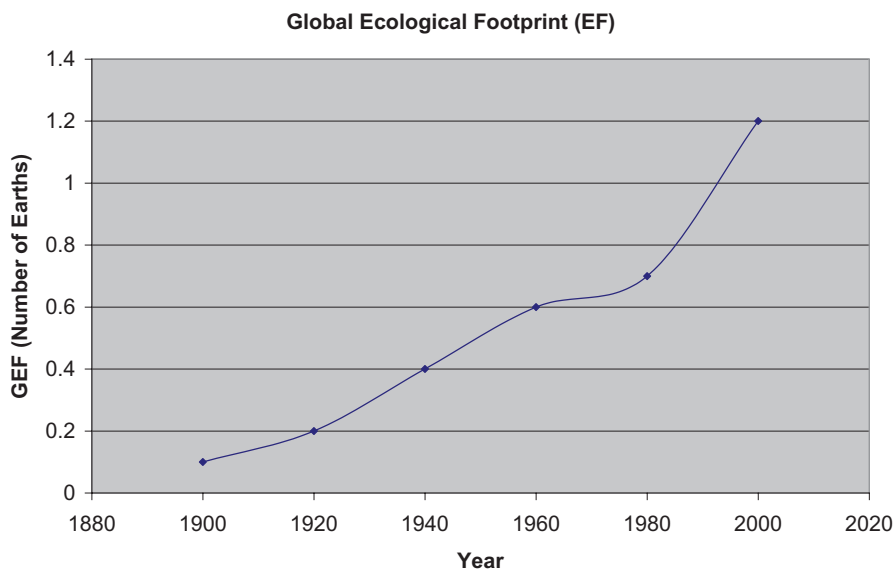


Fig. 1.4 Global ecological footprint

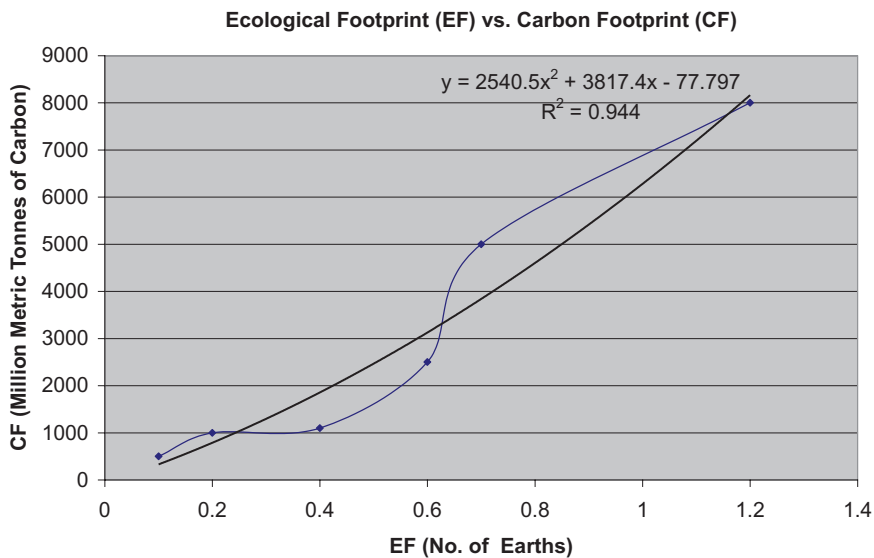


Fig. 1.5 EF vs. CF

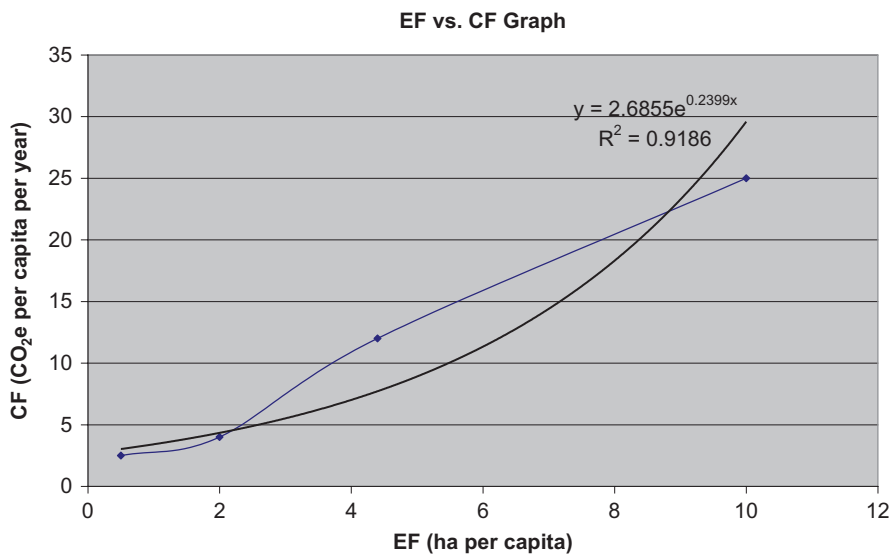


Fig. 1.6 Per capita EF vs. per capita CF

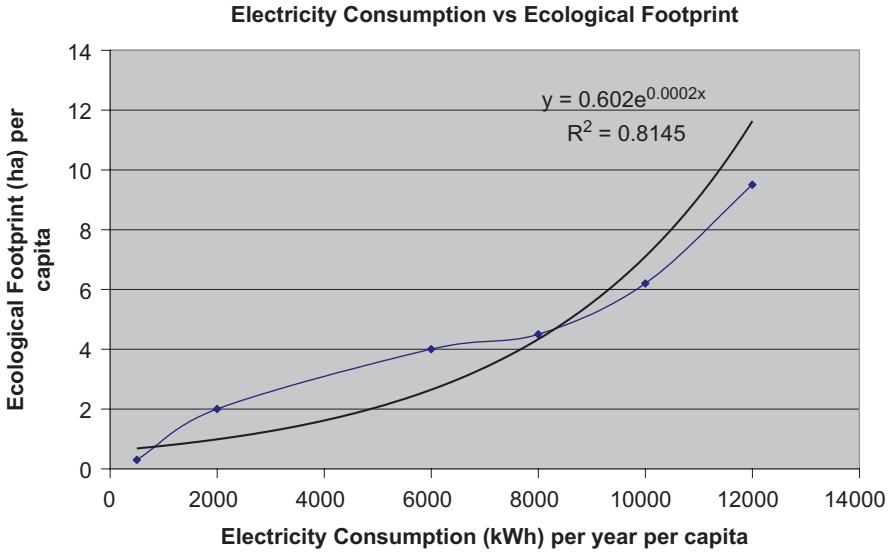


Fig. 1.7 Electricity consumption and ecological footprints

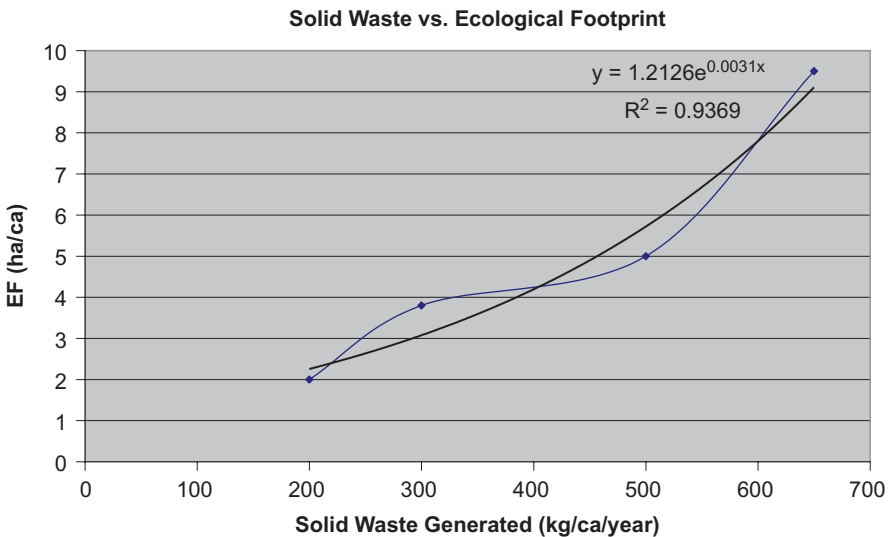


Fig. 1.8 Solid waste generated and ecological footprints

Our next attempt was to see if the concepts of CF and EF could be used for ranking of green buildings. Of all the parameters which we studied, we found that the maximum contribution to the EF and CF comes from electricity generation as has also been illustrated earlier (Fig. 1.2) and solid waste generation (Pandey 2009a, b; Pandey et al. 2009).

Information on electricity consumption for various countries was collected (<https://yearbook.enerdata.net/>) for which values of EF were reported (www.footprintnetwork.org). These values were subsequently correlated (Fig. 1.7). Similar exercise was done for solid waste generation (http://www.nationmaster.com/graph/env_mun_was_gen-environment-municipal-waste-generation) (Fig. 1.8). Correlation with electricity consumption was of the type $EF (\text{per capita}) = 0.602e^{0.0002(\text{Electricity consumed per capita})}$ ($R^2 = 0.8145$), while the same w.r.t. solid waste generation was $EF(\text{ha/c a}) = 1.2126e^{0.0031(\text{solid waste generated per capita})}$ with $R^2 = 0.9369$. This exercise was done in order to explore the possibility of using these correlations for doing a quick assessment of the environmental impact due to an activity or an event.

9 Energy-Efficient Buildings (EEB): Climate Change Solutions (CCS)

Buildings contribute well over one third of global energy use and associated greenhouse gas emissions. Thus, they have a huge potential to achieve drastic emission reductions at various levels. Indirectly it means that energy-efficient buildings would result in significantly reducing the impacts and risks of climate change. For example, landmark structures such as New York City's Empire State Building, with 102 stories and 242,000 m² could help in achieving emission-reduction targets considerably [<http://www.ittefaq.com/issues/2009/12/14/news0794.htm>].

The current climate footprint from buildings is equivalent to 8.6 billion tons of CO₂ per year. It is further predicted to almost double to 15.6 billion tons of CO₂ by 2030. Additionally, there is continuously the pressure for constructing new housing complexes—so as to combat population growth, urbanization, and modernization. This is bound to lead to an almost doubling of existing building stock in developing countries by 2050.

In South Africa, the building sector accounts for 23% of greenhouse gas emissions. Moreover, investment in new buildings is expected to grow at the rate of around 2% per year. This would automatically result in a multifold increase in greenhouse gas emissions. Therefore, in terms of immediate solutions what is urgently needed is using improved building designs, technologies, and policy instruments. This would, inter alia, enhance energy efficiency up to 40–50% in new buildings.

10 Need for Urgency

The following areas need immediate attention:

- In order to achieve national GHG-emission reduction targets, buildings need to be given the highest priority.

- Nationally Appropriate Mitigation Actions (NAMA) should focus on enhancing energy efficiency as the most important means for reducing GHG-emissions.
- Investment in energy-efficient building programmes in developing countries should need continuous and consistent support from well-developed countries.
- Continuous monitoring and energy/environment audits are the most important segments of any well-intentioned and effective environmental management plan.

11 Cost Implications of Mitigation Measures

Many of the CF-calculators provide many mitigation measures as well as costs involved in implementing those mitigation measures. Some of the mitigation measures suggested by them are related to tree plantation. And the cost estimates include two important factors: (1) GHG-mitigation, which on an average works out to be per tree (0.3–4.0 tons GHG per tree) and (2) cost of every tree (approx. \$1–5). Other mitigative measures could be subsidizing energy through renewable (wind and solar) energy. These mitigation measures can, therefore, be grouped under the following categories:

- Restoration
- Renewable energy
- Energy efficiency

However, prices for mitigation may vary between 3 and 30 USD per ton of GHG.

12 Conclusion

Inter alia, the chapter deals with the kind of research, which is needed in the area of Climate Change. Side by side, these researches need to be extended and pursued further so as to strike a balance between ecology and economy. Future exercises are needed, which should aim at the dynamics of Ecological Footprints (Pandey and Joseph 2001; Pandey et al. 2001a); analysis of Environmental Risks by way of developing models which deal with the issues like Temporal Risk Gradients (TRG) (Pandey et al. 2001b); and Ecological Economics of Natural Resources (Pandey et al. 2004). There is also a need for quantifying region-specific emission factors for different GHGs (Pandey et al. 2007). On the basis of these emission factors, region-specific ecosystem health (Pandey and Khanna 1992a) and human health risk assessment (Pandey and Khanna 1992; Pandey et al. 1992, 1993, 1994, 2005) can be carried out. Subsequently, appropriate region-specific environmental management plans can be developed. Ecology works very much on the concepts of species-specific, ecosystem-specific, and process-specific bio-rhythms (Pandey and Khanna 1995). It has a perfect analogy with the way a musical concert or consortia works or

in terms of Electronics Engineering, the way an integrated circuit (IC) works. All these features form a portion of Ecological Engineering.

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