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Green Urban Development: A methodology to calculate site and infrastructure related GHG emissions

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Abstract The built urban infrastructure which includes the various types of residential and commercial buildings, the parking and public transport network, water and electricity networks, and delivery mechanisms determine the energy use and carbon emissions of our city.

At Building level, controlling resultant GHG emissions could be done through measures such as better insulation, more efficient heating and cooling systems, and the installation of rooftops solar photovoltaics. IFC's EDGE (Excellence in Design for Greater Efficiencies) certification has addressed the need for a mass market tool to identify such opportunities and provides third-party validation of achievement of resource efficiency in buildings. EDGE certification rewards developers who implement strategies to reduce energy and water use in their buildings and embodied energy in materials.

At Precinct level, dense, mixed use urban developments that are close to public transit nodes give people convenient, less polluting transportation options while maximising resource use and improving their access to more job opportunities and higher quality of life. To encourage such "Green Urban Developments," IFC is piloting a new concept to quantify urban strategies such as location, transportation options, achievement of optimum density, overall configuration, planning, and layout to reduce waste all the while ensuring comfort and affordability. The aim is to influence private and public-sector developers to choose "Green Urban Development" design options early in the project planning process.

This paper presents a methodology for calculating GHG impacts of the site and horizontal infrastructure options for an Urban Development and explains the benefits and challenges of putting such a concept into practice.

1. The context

1.1 Introduction to EDGE

EDGE, a green building certification system, is available in more than 140 countries. An innovation of IFC (International Finance Corporation), a member of the World Bank Group, EDGE has been used to assess and certify more than four million square meters of building floor space since October 2014 [1]. EDGE is a simple, smart and inclusive certification system applicable to residential, retail, hospital, hotel, school and office buildings across the price spectrum. The EDGE application ties into IFC's broader programme on Green Buildings, which includes investments and broader market development [2].





Figure 1. Examples of EDGE certified projects, with countries where EDGE certification is available marked in green.

Using a free access online application (www.edgebuildings.com) incorporating a locally contextualised simulation engine, EDGE empowers the discovery of technical solutions at the early design stage to reduce operational expenses and environmental impact. Based on the user's basic information inputs and then selection of green measures, EDGE provides projected operational savings and reduced carbon emissions within minutes. This overall picture of the financial and environmental performance of a building helps to articulate a compelling business case for building green.

The suite of EDGE tools includes building type specific design simulation engines connected to user guides providing both technical explanations and procedural guidance on certification.



Figure 2. Screenshot of EDGE online application showing the energy section for homes

The EDGE Application is a key assessment platform that aims to accomplish the following objectives [1, 3]:

- A global solution for green buildings: more than 140 countries across the world would be able to use the app. this app is not only a rating tool but also provides the users with benchmarking and simplified energy simulation capability with minimal complexity and training requirements.
- An investment-planning tool for building owners and developers: edge app enables quick but well-informed decision-making. building owners and developers can understand the nuances of green investment and the returns on investment that they would be able to expect.
- An assessment tool for financial institutions: financial institutions currently lack a simple and effective tool by which they can judge the financial viability of a green building investment. Moreover, there is no global standard available by which they can assess risk reduction from lower utility bills. The EDGE Certification system provides the basis on which financial institutions can benchmark a building as 'green.'

While EDGE certification tackles the resource efficiency of buildings, the question is how can the program be made to accommodate and solve large scale urban issues? How can the success in quantifying efficiencies in buildings be leveraged to improve the sustainability of larger, more complex urban developments?

1.2 Need to tackle carbon intensive urban sprawl

The urban infrastructure of our cities, the types of residential and commercial buildings, the parking and public transport network, water and electricity networks, and delivery mechanisms determine the energy use and carbon emissions of a city. Research suggests that roughly 30% of "committed" future greenhouse-gas (GHG) emissions will occur as a result of new buildings and transport systems in a city. Energy-inefficient and carbon intensive urban developments can, therefore, lock us in on a high emissions trajectory.

Controlling greenhouse-gas emissions from standalone buildings can be achieved through better insulation, more efficient heating and cooling systems, and the installation of small-scale renewable energy sources, particularly on rooftops. Broader strategies, such as achieving optimum density, overall configuration or massing, and planning layouts to reduce wastage while ensuring comfort and affordability, require careful analysis and consideration.

Car dependent urban growth at the fringes of the city, known as urban sprawl, is increasing GHG emissions and private transportation energy use [4]. Sprawling, relatively low-density urban settlements make public transportation investments untenable, as there are fewer people to the bus or metro service for each transportation node. Research has also shown that low density urban forms compared to high density urban forms could increase global energy use by 2200 to 2500 TWh in 2050, equivalent of to around 10% of electricity use today [5]. A Canadian study that compared high and low-rise residential density showed that low- density suburban developments were twice as carbon intensive as compared to high-density developments on a per capita basis [6].

On the other hand, research has shown that dense, walkable, mixed-use urban developments that are close to mass transit nodes can reduce private car usage by 85% [7]. Many cities have mass transit options in place (or are in the planning stage) [8] but are yet to fully adjust urban planning controls to maximise the benefits. It is therefore important to assess opportunities beyond the boundary of a building such as benefits of mixed-use, higher density, and location (access to public transportation and amenities). Developers, investors, planners, and designers need a way to weigh the pros and cons of various site location options for their development. They also need tools for the masterplanning process, before embarking on detailed building design and procurement. These tools need to identify design and technology options to improve the environmental impacts and quantify the cost savings and investment paybacks associated with such options.

1.3 Available tools to quantify urban developments

Currently, there are two main types of tools available to quantify the environmental impacts and resource efficiency for the broader urban contexts. These are green rating systems or complex multi-domain dynamic modelling software.

1.3.1 Green rating systems

LEED for Neighbourhood Development or BREEAM Communities are well-known rating systems that take the green certification concept beyond individual buildings and apply it to the neighbourhood context as well as large-scale development plans [9, 10]. Local indigenous systems are also emerging, but most use the basic platform outlined in LEED or BREEAM. These systems have the following inherent limitations:

- a. They award 'credits' or points for environmentally beneficial choices under different siloed categories and do not attempt to measure a wholistic calculated value (such as CO₂ emission per year or total resource consumption) for the overall performance.
- b. They make subjective judgments [weighting] of different environmental issues [smart location, energy consumption, Neighbourhood Pattern] in the name of contextual economic and social concerns or priorities.
- c. They do not provide efficiency improvements and related capital cost and savings of technology solutions.
- d. Investors, banks and financial institutions need to be able to assess the financial viability of a Green investment through reduced risks from lower utility bills, which is not directly possible with the present rating systems [3].

1.3.2 Complex multi-domain dynamic modelling software

Urban scale models analyse a wide variety of aspects (buildings, transportation, water, waste, etc). This requires that these simulation models contain an assembly of inter-linked sub-models [11].

The analytical models that forecast resource use or GHG emissions of an urban scale rely on dynamic simulation software such as EQUEST [12], DesignBuilder [13] and EnergyPlus [14] for buildings energy demand simulation and MatSIM [15], CUBE Dynasim [16], EMMIE [17], SimTraffic [18], and Paramics [19] for traffic simulation as well as GIS based systems for urban developments. These software packages are complex to use and require a large amount of data to calibrate the energy use/transport/land-use models, which impedes their wider adoption [20]. The need for a large amount of information upfront means that they are rarely used for masterplanning design and specification stage in the initial conceptual stage. This results in many iterations to the design and time and cost overhead for the urban development project.

The above limitations restrict large-scale adoption of the existing tools, especially in developing countries. Most existing green urban development modeling tools are complex and time-intensive, as they require considerable investment in training and a laborious data entry effort, making it unnecessarily difficult to use. This underscores the need for a simple, quick, and affordable tool that focuses on the efficient use of land, transport, energy, water, and materials while exposing investment costs and length of payback time. As models grow complex, there is a point at which there are diminishing returns. A simple 'quasi-steady state' model [21] can offer a useful mental tool that can inform effective decision-making rather than a faithful representation of the truth. This is especially true for complex systems such as models for urban lifestyles as there is a high degree of stochastic uncertainty in the behavior and material working of urban environments [22]. In spite of the complexity, however, empirical investigations show that behavior conforms to discrete patterns following broad universal organizing principles (for example, [23,24 and 25])

With these current circumstances in mind, the IFC team is expanding the EDGE platform which currently models the vertical development (i.e., buildings) to include the horizontal development (location, site, people density, layout, bulk infrastructure) under a pilot tool named EDGE "Green Urban Developments" (GUD).

The aim is to influence private and public-sector developers to choose “Green Urban Development” design options early in the project planning process.

1.4 Green Urban Developments (GUD)

Green Urban Developments (GUD) can range from projects built around or together with transit stations, i.e., Transit Oriented Developments (TOD), to mixed-use ‘in-fill’ development and ‘green townships’ where transit is incorporated into the masterplan. The typical features of these GUDs are (adapted from [26,27,28 and 29])

- a) Mixed-use development that includes shops, schools and other public services, and a variety of housing types and prices.
- b) High density and compact development to maximise land use and improve affordability.
- c) More energy, water, and waste efficient design of buildings and infrastructure
- d) Public transit stations or transit corridors that are easy to access, reliable, and secure, as well as street and road planning for non-motorized transport.
- e) Pedestrian and bicycle friendly street and road planning. Streets should have good traffic calming features to control vehicular speeds.
- f) Restriction on car parking to discourage private vehicle ownership.
- g) Public and private sector participation.

GUDs can provide substantial cost savings for both city governments and citizens. A recent study concludes that China could save \$1.4 trillion in urban infrastructure costs if its urban development plans prioritise optimum density over sprawl [30].

Incorporating transit into urban design allows developers to benefit from stable or higher property values. Mixed-use settings also create commercial opportunities that benefit from increased foot traffic in the area. A developer may also be able to access government incentives for such projects. Hong Kong, for example, has created a financially successful rail and property funding model, encouraging the Mass Transit Railway Corporation to partner with individual private developers to build along new and existing rail lines [31].

Planning and policy innovations have also been critical for green urban development. In Barcelona, super-blocks [32] that combine city spaces into pedestrian friendly, car-free mini grids have been designed.

Copenhagen has used a “finger plan,” an urban plan, composed of five well-defined linear corridors (or “fingers”), separated by green wedges with open spaces, water sheds, and ecological preserves, to drive green growth [33]. Only compact, mixed-use developments are permitted around train stations to ensure a sustainable urban form.

Curitiba created structural corridors to promote job creation and activities away from downtown and inner-city locations and included housing and commercial density around mass transit lanes. As a result, the city has Brazil’s lowest relative car use per resident [34]. The commercial success of the urban design has allowed the government to integrate low-income social housing using cross subsidies from market-priced private sector housing.

Developing a reliable transportation system requires large capital expenditure, but a substantial pool of users will offset the costs over time. Decreased pollution and fuel consumption will provide economic benefits to users, governments, and companies while enhancing a city’s ability to maintain its competitiveness and environmental sustainability.

Reducing residents’ dependence on private vehicles could help decrease their overall living expenses while improving health outcomes by increasing physical activity and improving air quality. Living in such developments can increase a sense of community and wellbeing for residents and help improve living standards.

2. EDGE application for Green Urban Developments

As with EDGE for Buildings, the EDGE for GUD is intended to be a web-based application, usable across geographies and pitched mainly to private sector developers, as a scenario evaluation and investment planning tool. It is envisaged that EDGE certification for GUD will allow identification of projects by investors and end-users.

The EDGE GUD will calculate environmental impacts (including, GHGs and resource used), costs (capital and operational) for design options generated by the system which will be ballpark estimates only but will be sufficient to illustrate the value of going green and to commit to the next step.

2.1 *The EDGE GUD Standard*

To meet the minimum requirements of the EDGE GUD standard, a project must achieve 20% GHG savings (resulting from measures to reduce passenger transportation, energy use of buildings and solid waste management measures) and 20% water savings, compared to a city-specific base case [1].

EDGE focuses on resource efficiency for a streamlined approach that enables market adoption of green buildings at scale because most actions reduce operating costs. The process is simple, with only a handful of measures required to reach the minimum requirements. The results include reduced emissions, lower utility costs, extended equipment service life and reduced pressure on natural resources.

2.2 *The EDGE modelling process*

2.2.1 *The Base Case*

The first step in assessing the efficiency of a design is to establish a project specific Base Case. A designer enters basic project data (e.g., size, location, building types, etc.) into the EDGE software, which calculates the project “Base Case,” by drawing upon location-specific databases for parameters such as climate, business as usual practices and local usage patterns.

To encourage early-stage planning of green options, the EDGE software suggests many default options to a designer who has not yet decided on the details of a project. These defaults are accessible to the user to modify as required.

Defaults include city, country and regional data describing:

- Population and population density, income levels;
- Transportation data, including modal split, average trip distances, vehicle load factors and fuel efficiencies;
- Employment;
- Planning requirements, including parking provision, open space provision, block sizes, etc.;
- Utility tariffs, carbon intensities, infrastructure level losses;
- Solid waste and wastewater;
- Building energy performance for selected building types.

2.2.2 *The Improved Case*

An “Improved Case” is then created, when the user selects technical measures for inclusion in the design. If Improved Case GHG emissions are at least 20% less than the Base Case, a development meets the EDGE standard. In addition to energy savings, the EDGE software also reports water savings, GHG emission avoidance, and operational cost reductions. The incremental costs for the selected technical measures and the payback period from savings are also presented.

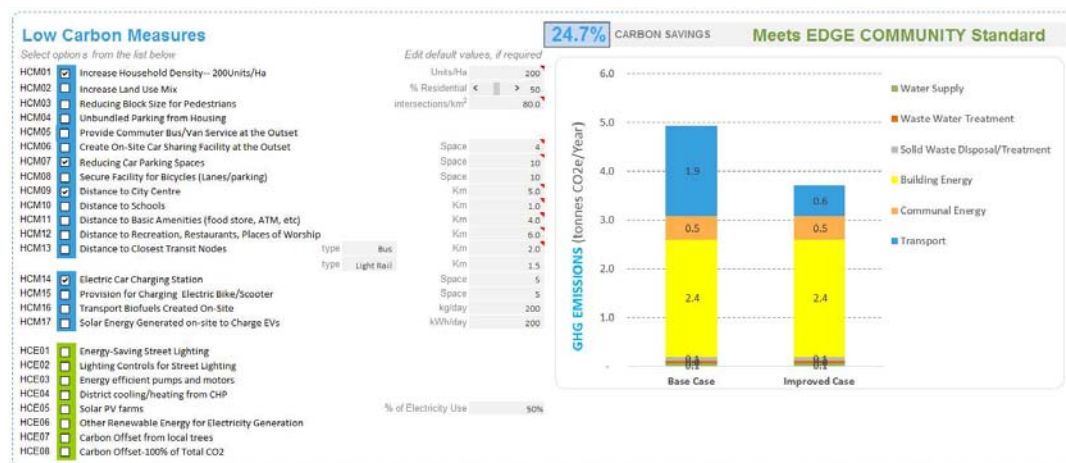


Figure 3: Screenshot of prototype EDGE GUD application

Modelling of the impacts of selected technical measures engages a number of 'engines', within the software tool, which calculate the interrelated impacts of these measures on specific key performance indicators. These indicators currently include:

- Operational GHG emissions;
- Transportation passenger and vehicle kilometers travelled;
- Building and Infrastructure related energy consumption;
- Water consumption, per source;
- Solid waste arisings, treatment and disposal, per fraction;
- Wastewater treatment and disposal;
- Employment within the proposed development.

2.3 The modelling 'Engines'

2.3.1 Employment Engine

The Employment Engine utilises the user's description of the proposed development to derive an estimate of employment opportunities, by broad job category¹, using a notional proportion of category and density of employment within each building type in the development. These categories are mapped within the tool to provide an assessment of local housing demand for these employees, for comparison to the developer's proposed residential housing provision.

The Employment Engine also calculates estimated working population within the proposed development, as a basis for calculating commuter transportation demands, linked into the Transportation Engine.

2.3.2 The Transportation Engine

The Transportation Engine estimates the impact of selected measures on person and vehicle kilometre travelled (PKT and VKT) and the resultant carbon emissions. The engine assesses these impacts based on the following location and project characteristics:

1. Increase population density

¹ Job categories are based on U.S. Equal Opportunity Commission - <https://www.eeoc.gov/eeoc/statistics/employment/jobpat-eeo1/glossary.cfm>

Litman, 2010 [36] suggests that an increase of 10% in people, or jobs, per unit of land typically reduces VKT between 0.5% and 1%, as an isolated factor, increasing to around 4% where associated with greater regional accessibility, transportation mix, etc.

- b. Residents working within the development (job creation and mixed-use)
Commuter travel calculated based on employment creation within the development and estimated commuting out of the development into the nearest city.
- c. Reducing block size for pedestrians
Rowe, et al. [37] found that per household vehicle ownership rates decline significantly with smaller block size and increased roadway connectivity.
- d. Unbundling parking from housing
UCLA's California Center for Sustainable Communities [38] suggests that unbundling of parking provision from residential provision results in an overall decrease in vehicle kilometers travelled (not person kilometers travelled), due to a resultant reduction in vehicle ownership within the new development.
- e. Provide shuttle bus/van service at the outset
Assuming a proportional uptake of this service by commuters, with an estimated reduction in VKT for private vehicles.
- f. Create an on-site car sharing facility at the outset
Martin and Shaheen [39] provide insight into the impacts of carsharing on VKT, including the impacts of use of public transport modes. Within the Transportation engine, the provision of carshare parking spaces, and car share club members is used to estimate an overall reduction in VKT within the development.
- g. Reducing car parking spaces
Litman, 2010 [36] suggests that the supply, pricing and management of available parking can reduce private automobile trips between 10% and 30%.
- h. Secure facility for bicycles (lanes/parking)
The Transportation engine estimates the reduction in private vehicle usage, resulting from increased facilities for cycling within the new development.
- i. Person and Vehicle kilometers travelled are modelled for each mode of transport, derived from user input and default values for:
 - Distance to city centre
 - Distance to schools
 - Distance to basic amenities (food store, ATM, etc.)
 - Distance to recreation, restaurants, places of worship
 - Distance to closest transit nodes
 - Distance to other amenities

The engine also considers measures to switch the fuel used for transportation, including:

- j. Electric car charging stations
- k. Provision for charging electric bike/scooters
- l. Transport biofuels created on-site
- m. Solar energy generated on-site to charge EVs

2.3.3 Energy engine

The energy use across the site is considered by the Energy Engine. The predicted energy use of each building type (using default building energy performance data for the region / country / city, derived from related EDGE models).

The engine also calculates site wide infrastructure energy uses, such as street lighting [40, 41], water pumping and distribution [42], district heating and cooling and solar farms. The emission factors for different energy uses are used to arrive at energy related carbon emissions.

2.3.4 Water engine

Calculation of water use across the site, by the Water Engine, considers the predicted water usage of each building type, using default water consumption data from related EDGE models, and site wide water uses such as open space landscaping and infrastructure distribution losses. Electricity consumption relating to water abstraction, transportation and treatment is used to calculate water related carbon emissions within the energy engine.

Wastewater demands for the Base Case and Improved Case are calculated, together with estimated resultant GHG from distribution, treatment and disposal activities.

2.3.5 Solid waste engine

The solid waste engine estimates tonnages of municipal and commercial solid waste arisings, using the Base Case and Improved Case development details. The engine uses waste profile data for the region, country and city (where available), to determine approximate waste fractions and prevailing local treatment and disposal practices for the Base Case.

Solid waste arisings and fractions are calculated using regional, country and city specific data, where available, coupled with the income level associated with the development [43, 44, 45, 46, 47].

Users can influence their Improved Case carbon emissions, relating to solid waste management, through a set of measures including:

- a. Introduction of municipal waste management systems;
- b. Material recovery and recycling facilities;
- c. Bio-digesters for food waste treatment;
- d. Other waste to energy opportunities;
- e. Industrial/commercial waste exchanges.

2.4 Innovative Features of the EDGE GUD Tool

Some of the innovative features of EDGE GUD are:

- The EDGE GUD is the first tool to quantify the benefits of a variety of land use, urban planning and transportation interventions, along with the benefits of improved efficiencies in infrastructure and built-environment. For example, the tool enables users to quantify the GHG benefits of developing in city centre locations, creating mixed used developments, reducing parking and providing infrastructure for electric-vehicles.
- Weighting indicators to suit different climate zones: the data from individual cities have been incorporated into the GUD tool, and therefore the predicted performance reflects that of the real-case scenario.
- Translation of green practices into economic savings: The GUD is the first tool to quantify the benefits of a variety of land use, urban planning and transportation interventions, along with the benefits of improved efficiencies in infrastructure and built-environment. For example, the tool enables users to quantify the GHG benefits of developing in city centre locations, creating mixed used developments, reducing parking and providing infrastructure for electric-vehicles.

3. Making it happen

The EDGE GUD software is an entry point; an enabler; a point of entry. To effectively scale green urban developments both market and policy mechanisms will be needed, such as:

- Developing a GUD or TOD policy framework for integrated infrastructure planning that develops sustainable urban growth centres with high-density mixed land use.
- Reforming land-use regulations such as single-use zoning, low-density limits, and high parking fees to encourage mixed-used, transit-oriented developments with reduced car parking. These should be combined with effective policy changes such as mandating reduced maximum car parking for homes rather than a minimum.
- Redefining policy definitions of affordable housing to include the combined cost of housing and transport, e.g. Housing +Transport Index [35].
- Creating incentives for the private sector. Cross-subsidization using tax abatement or value capture methods could help make the higher costs of transit-accessible locations less prohibitive for private developers and investors.
- Exploring alternative implementation options, including Public-Private Partnerships (PPPs), to leverage private sector skills and financing to develop projects.
- Encouraging corporations to locate offices within green urban developments as an anchor tenant or employer through financial and non-financial policy incentives.

By using EDGE GUD at the start of a project, the intent is to draw the user in, so that the software affects the way the developer does business. Due to the current speed of industrialized development, most consideration of sustainable building elements happens at the end of the project when its implementation is already too late no longer practical or cost effective. As with most green certification systems, there is always the question of whether these efforts yield any real efficiency benefits.

Longer-term evaluation is challenging, of course. Future modifications to the software and a communication strategy aimed at occupants will consider these ever-present issues. EDGE GUD will continue to be test piloted repeatedly across various markets to ensure the accuracy of results and will remain open source, allowing other professionals to finesse it over time to ensure the highest level of integrity.

EDGE GUD will be rolled out on a pilot basis across projects. The feedback gained will be used to improve and debug the product in preparation for its first launch.

4. Conclusions

Learning from EDGE buildings certification, EDGE GUD can expand the reach to communities and neighbourhoods with wider application. The inclusion of transport and urban elements such as parking and waste management brings a fresh perspective on how best to create greener/cleaner cities.

There are a variety of reasons why developing countries would benefit from the wide-scale adoption of Green Urban Development practices. Not only would there be a reduction in built-environment-related GHG emissions and better use of land, but there would be positive economic benefits from less fossil fuel imports, fewer infrastructure investments, reduced utility costs, and the birth of a new sustainability industry. Since most of the urbanisation in the coming decades will be in developing countries, it is essential that a classification system exists that correlates directly to the unique drivers of these marketplaces. One that Improves the quality of life with better places to live work and play.

By lessening environmental impacts while simultaneously providing cost incentives, EDGE provides the financial traction that has long been missing to gain momentum from investors, buildings owners, and developers, by providing a strong catalyst for green buildings and communities in emerging markets.

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