The Built Effects on Global Environment

- Environmental Impact Assessment of Building Sector

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Abstract: The Built has an influence on Global Environment through urban heat island effect (UHI), increasing of energy consumption and CO_2 emissions. Communities are fast changing from rural to urban regarding to urbanization. According to the United Nations World Population Prospects Revision Report (2001) by the year 2030, 60% of the world's population will live in cities. Since the building sector is one of the largest energy consumers in cities, work in this paper is focused on its influence on the global environment. In addition, possibilities of usage Life Cycle Assessment (LCA) and Life Cycle Energy Assessment (LCEA) of buildings, in cities decision-making process is shown through case studies.

Keywords: *Built environment, Building Sector, Energy Efficiency, Life Cycle Assessment (LCA), Life Cycle Energy Assessment (LCEA)*

1. INTRODUCTION

One of the biggest challenges in modern urban planning and sustainable building are embodied energy and life cycle assessment of materials. Moreover, how much energy steel, concrete and wood products are used for its production, transport, usage, maintain and, in the end, disposal. Furthermore, what is the impact in the way of emissions that all this process have on the environment. If we take into account the choices people conduct once construction is finished, it is easy to make the conclusion that development standards have tackled the problem of total energy and sustainability impacts just in a small scale.

As we can see, today 50% of the world population lives in cities, but till 2050 is expected to increase up to 84%. Cities as centres of innovation are facing a combination of key environmental and socio-economic drivers of change which include: climate change, rising energy prices, demographic change, social inclusion, information technology and global competitiveness (Dixon 2011). Expanding of urban living leads to increasing heat island effect as well as higher demand of cooling systems and the deterioration in air quality.

Cities built environment is one of the biggest CO_2 emitter and energy consumer. The built environment includes buildings, infrastructure, transport and human community, cultural experiences and interaction of people. But since 40% of all primary energy production worldwide is used in the building sector, my work will be based on this sector (Utama & Gheewala 2009). The activities in the residential building sector have high initial and follow-up expenditures, long life-cycles and require a large amount of materials and energy. Thus, CO2 emissions are significant. Unfortunately, projects and legislation are based on short payback times on a few years.

It is becoming increasingly difficult to ignore the need for improvements in the urban planning process and existing policies regarding to the building sector. Therefore this paper will focus on one side on impact of the built (building stock) onto the global environment. Benefits of using tools such as Life Cycle Assessment (LCA) and Life Cycle Energy Assessment (LCEA) in the decision making process referring to energy consumption and CO_2 emission in the built environment will be shown through best practice examples on the other side.

2. BACKGROUND

It is obvious that a crucial reason for population fluctuation from rural to urban areas is urban build environment. Since more and more people are coming into cities searching for place for living, natural landscape is being changed into the built environment. Consequently new roads and buildings absorb more solar energy and generate higher temperature (10-20®C) regarding to the air temperature in the surrounding area. Overall, the whole city becomes hotter than rural area around the city, approximately 1–3°C, this is known as urban heat island (UHI) phenomenon (Golden 2004). United States Environmental Protection Agency (EPA) points out that the UHI can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions and so on. This represents a pointer to the urban built sector bad influence on the global environment and urgency for improvements in the urban planning process. Moreover, the necessity of using tools such as life cycle assessment, life cycle impact assessment and life cycle energy assessment in everyday decision making process.

Standard environmental impact assessment (EIA) for building stock barely refers to a single project or its phase. That means that EIA is not taking into account environmental emission and energy usage in the complete consumption system (Balaras et al. 2003). Thus, life cycle assessment (LCA) is crucial for understanding the environmental performance of buildings especially in the evaluation process of a product effects on the environment over the entire period of the product's life. The benefit of this is on one hand that resource-use efficiency is increasing and on the other liabilities decreasing. For all this reasons, LCA is usually called "cradle-to-grave" or ''cradle-to-cradle'' analysis (Sabol 2008). Life Cycle Assessment can be for new, existing and refurbish buildings. Units for tracking flow for existing buildings LCA are primarily mass, energy consumption, volume and other physical units of buildings. So far the application of LCA to buildings has stayed in the domain of research groups – along with a few private sector firms that are trying to establish different LCA software and rating systems (Kohler & Moffatt 2003)

By existing software (ATHENA, BRE-''Envest'', IVAM-'' Eco-Quantum 3'', SBI-''BEAT "2000'', US EPA-''BEES'') LCA can be used for analysis about:

1. Embodied primary energy use
2. Global warming potential
3. Solid waste emissions
4. Pollutants to air
5. Pollutants to water and
6. Natural resource use of buildings.

Unfortunately most software's used for measuring building energy efficiency are not taking into account energy usage through whole ''building life''.

Thus, Life Cycle Energy Analysis (LCEA) which is used for measuring energy consumption, both operational and embodied, should be more promoted and used in the process of building energy efficiency decision making. LCEA concept can be used to demonstrate the life cycle benefits of strategies designed to optimize the operational energy or embodied energy of a building (Fay, Trealoar and Iyer-Raniga 2009). LCEA usage benefit in the decision making process is reflected in more optional choice of energy efficient materials, systems, and processes for the life cycle of buildings. The impact categories of LCA methodologies vary from system to system. (Dr. Bayer et al. 2010)

In following chapter's bigger attention will be devoted to the case studies of countries and cities which made good practice examples and results of the buildings Life Cycle Assessment (LCA) and Life Cycle Energy Assessment (LCEA), successively.

3. LCA AND OFFICE BUILDINGS

LCA was first time used in 1969 in Coca-Cola for comparison of resource consumptions and environmental releases. Currently LCA has been internationally standardized by ISO 14040. In the building sector LCA can be applied for assessing its environmental impact. Difficulty that appears here is that every building has different characteristics and local impacts are different. Building LCA includes construction, use and demolition phase. (Dimitrokali, Hartungi and Howe 2010) Since existing LCA studies are more orientated on residential than on commercial buildings first part of this research will show the importance of LCA usage in case of office buildings.

3.1 Office building – UK

With regard to office building stock, in the UK, is recognized higher energy consumption in terms of embodied energy (manufacturing, construction and maintenance) then operational one (lightning, cooling, warming and ventilation) compared to dwellings. Four different types of offices were taken into account regarding to their CO_2 emission ($KgCO_2/m^2$/year):

Type of Office Building	Office Characteristics	$KgCO_2/m^2$/year – typical rate	$KgCO_2/m^2$/year – lowest rate
100 - 3.000 m^2	- naturally ventilated - simple control systems for artificial lighting - limited common spaces and catering areas	56.8	32.2
500 - 4.000 m^2	- naturally ventilated - higher light levels - higher use of office equipments - with cellular offices and conference rooms	72.9	43.1
2.000 - 8.000 m^2	- air-conditioned - standard office types - deeper floor areas	151.3	85.0
4.000 - 20.000 m^2	- air-conditioned - wide range of equipment - built for a purpose (e.g. head or regional offices)	226.1	143.4

Table 1. The four different types of office buildings in UK (CIBSE 2000)

If we take into account that 1GJ of electricity produce 170Kg of CO_2, figures from above table represent that energy consumption and CO_2 emissions are increasing swiftly in all the office types. Moreover, during this study it was found that between 80% - 90% of total energy consumption and CO_2 emissions are due to electricity consumption for office air-conditioning (CIBSE 2000).

3.2. Office building – Thailand

In Thailand office building stock consumes 43.5% of electricity. Moreover, it is notable that offices have mostly the same characteristics. In this case study office building is in the central business district of Bangkok and its characteristics are following:

1. Gross floor area – 60,000 m^2
2. Gross volume – 9, 120,000 m^3

3. Office floors – 38
4. Structure – Concrete
5. Year of service – 50

The LCA was based on major construction components and included the manufacturing, construction, operation, maintenance and demolition phase, transport was also integrated into account. The results showed that steel and concrete have the biggest influence on environment, retrospectively 17% and 64% of life cycle greenhouse emissions. Overall, operational energy use has bigger impact on environment and amounts 52% of life cycle greenhouse gas emissions, embodied energy influence is less with 34% of life cycle greenhouse gas emissions. One of the impact assessment results disclose that 40 percent of the complete operational energy impact is produced by lighting, air conditioning, office equipment and other office appliances. Further result of the assessment expose that savings in electricity consumption can result in reduction of 820 tCO_2/year, 3.37 tSO_2/year and 45 kgC_2H_4/year. (Kofoworola & Gheewala 2008)

A key problem in this part of the research is leak of the literature and different approaches in relation to life cycle assessment of office building.

4. LCEA AND RESIDENTIAL SECTOR – AUSTRALIA

Life Cycle Energy Analysis (LCEA) uses energy as the only measure of environmental impact. Important role in LCEA analysis is played by both embodied and operational energy during the whole building life (Fay, Trealoar and Iyer-Raniga 2009). In general, the more advanced studies on building sustainability and on their LCEA have been conducted in Countries such as Australia, New Zealand and North America.

Life Cycle Energy (LCE) is calculated with following equation:
LCE = EEi + EErec + (OE * building lifetime)

EEi – the initial embodied energy of building
EErec – the annual recurrent embodied energy (e.g. maintenance)
OE – the annual operational energy

For LCEA case study is used “Green Home” residential project, two-storey detached brick house in Melbourne, Australia. For calculating embodied energy among other into account was taken paint, windows, plumbing and electrical systems, appliances and roofing materials. On the other side for operational energy consumption into consideration was taken not only energy needed for heating and cooling but also all consumption caused by household operations (e.g. cooking, lighting, hot water and so on). As we can see in table below supplementary insulation enlarged the embodied energy of the house from the outset by 1.1 GJ/m^2 of floor area. For the first 25 years the renovation rate was only 2.7% and increased to 5.6% over 100 years. Furthermore, Life Cycle Cost Assessment (LCCA) was conducted for additional insulation and payback period gained with savings in heating and cooling energy is 12.2 years.

Age of house (years)	Base case (GJ/m^2)	Plus added insulation (GJ/m^2) – higher embodied energy
0	14.1	15.2
25	43.0	44.1
50	76.0	72.6
75	108.8	103.1
100	140.4	132.5

Table 2. Life Cycle Energy for the house as constructed (Fay, Trealoar and Iyer-Raniga 2009)

By the Australian CSIRO (Scientific and Industrial Research Organization) an average of 0.098 tonnes of CO_2 is produced per 1 GJ of embodied energy.

It is important to notice that countries such as Australia and New Zealand have different building technologies which can barely be found crossing the Europe. So this is a good opportunity for further research and case studies of Europe buildings LCEA.

5. CONCLUSION

Research in the field of office buildings led me to the conclusion that life cycle was more focused on the commercial building envelope systems and CO_2 emissions than on the whole phase of buildings energy consumption. On the other hand, in the case of residential buildings there is a particular lack of studies referring specifically to LCA, LCEA of building retrofit and refurbishment. Further conclusion is that developing countries have great potential in sustainable planning and building than already developed countries.

To sum up, as we saw above the building sector has large potential of energy and CO_2 savings. Since operational energy consumption can be reduced with improved appliance, better lightning and air-conditioning systems importance for energy consumption reduction referring to building construction and material usage (embodied energy) is essential in this case.

REFERENCES

- Agya Utama, Shabbir H. Gheewala. Indonesian residential high rise buildings: A life cycle energy assessment. Energy and Buildings 41 (2009) 1263-1268
- Balaras C.A., Droutsa K., Dascalaki E., Hansen K., Petersen E.H.. Environmental Imapact Assessment of Residential Buildings. Conference paper. ILCDES 2003: Integrated Lifetime Engineering of Buildings and Civil Infrastructures.(2003) Rotterdam, Netherlands
- Bayer C., Gamble M., Gentry R. and Joshi S. AIA Guide to Building Life Cycle Assessment in Practice. (2010) The American Institute of Architects
- CIBSE. Energy Consumption Guide (ECON) 19 – Energy use in offices. 2000 http://www.cibse.org/pdfs/ECG019.pdf.
- CSIRO, 'Embodied Energy', CSIRO Manufacturing and Materials Technology, Sydney, http://www.cmit.csiro.au/brochures/tech/embodied
- Elisavet Dimitrokali, Rusdy Hartungi, Joe Howe. The applicability of LCA to assess environmental impacts of building technologies in buildings. The 16th Annual International Sustainable Development Research Conference (2010) Hong Kong, Paper Number:62
- Jay S. Golden. The Built Environment Induced Urban Deat Island Effect in Rapidly Urbanizing Arid Regions – A Sustainable Urban Engineering Complexity. Environmental Sciences, (2004) Vol. 00, No. 0, pp. 000-000
- Louise A. Sabol. Measuring Sustainability for Existing Buildings. IFMA World Workplace, November 2008.
- Niklaus Kohler, Sebastian Moffatt. Life-cycle analysis of the built environment. UNEP Industry and Environment April – September 2003 p.p.17-21 [4]Roger Fay, Graham Trealoar and Usha Iyer-Raniga. Life-cycle energy analysis of buildings: a case study. Building Research & Information (2000) 28(1), 31-41
- Oyeshola F. Kofoworola & Shabbir H. Gheewala. Environmental life cycle assessment of a commercial office building in Thailand. Springer- Verlag. Int J Life Cycle Assess (2008) 13:498–511
- Roger Fay, Graham Trealoar and Usha Iyer-Raniga. Life-cycle energy analysis of buildings: a case study. Building Research & Information (2000) 28(1), 31-41
- Tim Dixon. Sustainable Urban Development to 2050:Complex Transitions in the Built Environment of Cities. WP2011/5 October 2011
- United States Environmental Protection Agency (US EPA). Heat island effect. http://www.epa.gov/heatisld/