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Sustainable Urban Metabolism Practices an Understanding for Bangladesh

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The concept of urban metabolism helps to understand and analyze the way how societies (in large parts located in urban areas) uses their available resources, energy, land and all elements of the environmental system, for maintaining and replicating themselves. The urban metabolism is the study to confront the issues of quantification of the input, outputs and storage of energy water, nutrients, materials and wastes that are transferred into the built environment in a city. Europe is one of the most urbanized continents in the world; with some 75% of its population living in cities is experiencing the amplified consumption of resources as energy, land and soil as well as the need for more transport facilities & other infrastructural improvements leads to serious environmental problem. To come out from the environmental problems associated with the mentioned factors Europe is now practicing the sustainable urban metabolism approach in their planning concept. This paper explored the concept of sustainable urban metabolism practices in Europe and how can the concept be suitable for a country like Bangladesh. It is found that metabolically efficient cities are focused to the urban policy spatially focused densification, high density development with high quality public transport access, functional mix of urban quarters and combine urban and building reconstruction. Bangladesh is now experiencing high urban growth rate, in such context the development of efficient cities from sustainable metabolic point of view can only be achieved through the consideration of different urban policies at planning and development level. This paper has makes a first attempt at comparing the urban metabolisms of a few worldwide cities and tried to find out those issues that should be brought under consideration in the development process of cities of Bangladesh in our context.

Key words: Urban metabolism, energy consumption, densification, functional mix, urban policy.

1. Introduction

Human civilization as well as cities are continually developed and improved through the process of urbanization. Cities around the world have dramatically been expanding in size, density and complexity (Kaye et al., 2006). This dynamic process of cities' growth as well as urbanization can influence the different urban systems through its different dimensions. Expansion of cities' size, shape and population are among those. This rapid growth has supplemented by the dramatic change in the energy flows of inputs and outputs such as fuel, foods, waste, natural resources etc. The interaction of urban environment and natural environment is far less understood in this process of energy flows as input and output. The metabolic analysis helps attaining such understanding (McDonald & Patterson, 2007). The concept of urban metabolism helps to understand

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the overall process of the material input and output, analyzing the way societies use their available natural resources, energy, land and other elements of the overall environmental system, for maintaining and replicating themselves (Urban Audit, 2007). The way cities and urban areas are being built is greatly influencing the qualities and quantities of resources being used for maintaining the urban life. This process helps to understand the sustainable development mechanism through resource utilization and it can be compared with the metabolic processes of cities' different organs. With the rapid growing nature of cities, the understanding of its resource consumption and the metabolism becomes more important for policy makers and decision makers. This study on urban metabolism might help to pave the way towards a sustainable urban development of Bangladesh through proper resource management. This paper explores the ways to analyze different urban metabolism practices in different countries and tries to analyze this process in the context of Bangladesh.

2. Literature Review

The urban metabolism concept was developed by Abel Wolman (1965). This concept was established as a method of analyzing cities and communities through the analysis of inputs water, food and fuel, outputs – sewage, solid refuse and air pollutants and visualizing their respective transformations and flows. Wolman's influential research was the first attempt to highlight system-wide impacts of goods consumption and waste generation in the urban environment (Decker et al., 2000).Urban metabolism analysis appeared from a growing understanding of the limited availability of fossil fuels and their impacts on the environment as well as ideas about efficiency of that use. Different countries throughout the world have been using this concept to analyze the overall impact of the city on natural environment and from then trying to achieve sustainability. Towards achieving the sustainability at city level many of the developed and developing countries adopted different methods. Some of the measures applied at policy level while some of them are applied through different infrastructural measures to attain sustainability. Sustainability in metabolic is considered as the less input of non-renewable energy sources exploitation of ecosystem services in controlled way and rates. According to Morelli, 2013 for attain the sustainability from metabolic perspective it is important to transform the structure and functioning of a system, in such a way that it uses progressively less non-renewable energy sources and exploits ecosystem services at a rate that is smaller than the time needed for self-regeneration, while improving the living standards, environmental well-being and economic performance of human settlements (Vittorio GargiuloMorelli, 2013).

There are different methods to measure urban metabolism. Stephanie Pincetl (2012) identified and explained five methods of measuring urban metabolism i.e. Emergy, Material flow analysis, Mass balance, Life cycle assessment (LCA), Economic input output life cycle assessment (EIO-LCA) that are used to measure the urban metabolism. Among these, Emergy is used for non-urban analyses such as for agricultural production. Material flow is used to derive the indicators for sustainability while the Mass balance is used to find out the degradation of resources. The other two methods LCA and EIO-LCA are interlinked. LCA provides cradle for accounting of uses of resources and associated environmental impacts from extraction to disposal. On the

other hand, EIO-LCA adds economic factors to the LCA and provides ability to link money matrices.

3. Methodology

First, to understand the metabolic level of Bangladesh different types of metabolic data have been collected from secondary sources. Data on natural resources consumption and waste generation is collected for analysis to analyze the metabolic relations. Through the analysis of the collected data it is checked the deficiencies of our system to be a sustainable like European countries. Gaps and deficiencies of the metabolic process of Bangladesh to attain sustainability are compared with the different case studies around the world. These studies helped to generate a basic concept about the sustainable urban metabolism practices in European countries and in compare with them the difficulties and position of Bangladesh in sustainable urban metabolism practices. Here the overall findings of the study is briefed and some recommendations been provided for Bangladesh to attain sustainable urban metabolism like European countries.

4. Analysis & Findings

4.1 Analysis - Overall Metabolic Condition of Bangladesh

In this part of the study the overall metabolic condition of Bangladesh is framed by addressing the different metabolic data from secondary sources according to the different sectors i.e. food, water, energy, transport, waste generation and waste recycling.

4.1.1 Food

Bangladesh is primarily based on the agricultural farming mostly. Agriculture is the largest producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force ("CIA - The World Fact book, 2014). Though the overall production of the agricultural sector is good, the conservation of the crops hampering the overall development of the sector. Every year a big portion of the perishable agricultural goods gets perished away due to the lack of well conservation system. Despite the performance of this sector has an impact on major macroeconomic objectives like employment generation, poverty alleviation, human resources development and food security, it is making the overall economic development a slow process. In 2010, the average quantity of food items consumed was estimated at 1,000 gm i.e. one kilogram per capita per day at the aggregate level. It was 947.8 gm, 893.1 gm and 913.8 gm in 2005, 2000 and 1995-96 respectively. In rural areas, the average food intake was 1000.5 gm, 946.3 gm., 898.7 gm. and 910.5 gram in 2010, 2005, 2000 and 1995-96 respectively. In urban areas, the average food intake shows fluctuating trend over the period 1995-96 to2010. In 2010, it was estimated at 985.5 gm per capita per day which increased by 5.5percent after 2005.

4.1.2 Water:

Bangladesh is a land of rivers 57 rivers and 230 tributaries. But 93% of surface water comes from outside the country. Uncontrolled use of water resources generated different problems in Bangladesh such as decreasing level of ground water, water pollution by industrial wastes etc.
Extraction exceeding recharge
– Greater Rajshahi area • Groundwater table declined 3 meters between 2004 and 2010
– Dhaka • Groundwater decreasing by 3 meters per year
A total of 640 individuals participated in this cross-sectional study carried out in an arsenic-affected rural population in Bangladesh. In this study daily per capita water consumption for drinking purposes was found to be 73.04 ml/kg/d (range = 71.24-74.84 ml/kg/d),(Luby, 2013); (Mullick, 2010)
An average person consumes

- 30-300 litters per day for domestic purpose
- 3,000 litters per day to grow their food
- 3,500 litters for 1 kg of rice

(Turner K, et al. Economic valuation of water resources in agriculture. FAO paper reports, No. 2)

4.1.3 Energy:

Recent rate of Energy production (kt of oil equivalent) of Bangladesh is measured by World Bank at 26089.67 in 2011. Energy production denotes to forms of primary energy--petroleum (crude oil, natural gas liquids, and oil from non-conventional sources), natural gas, solid fuels (coal, lignite, and other derived fuels), and combustible renewable and waste--and primary electricity, all converted into oil equivalents. Electric energy is mainly generated using coal, gas and hydraulic power in Bangladesh. There is little applicability of renewable sources of energy in Bangladesh. Though hydraulic power generation system is a method of generating energy, the reliability on this source is limited in Bangladesh. The main electricity power stations are mainly based on natural gas and coal. It is seen in recent years that the reliability is increasing in gas powered electric stations rather than the hydraulic powered stations for electricity generation. More than three-quarters of the nation’s commercial energy demand is being met by natural gas. This influential sector caters for around 40% of the power plant feedstock (Sunny, 2013); (Bank)

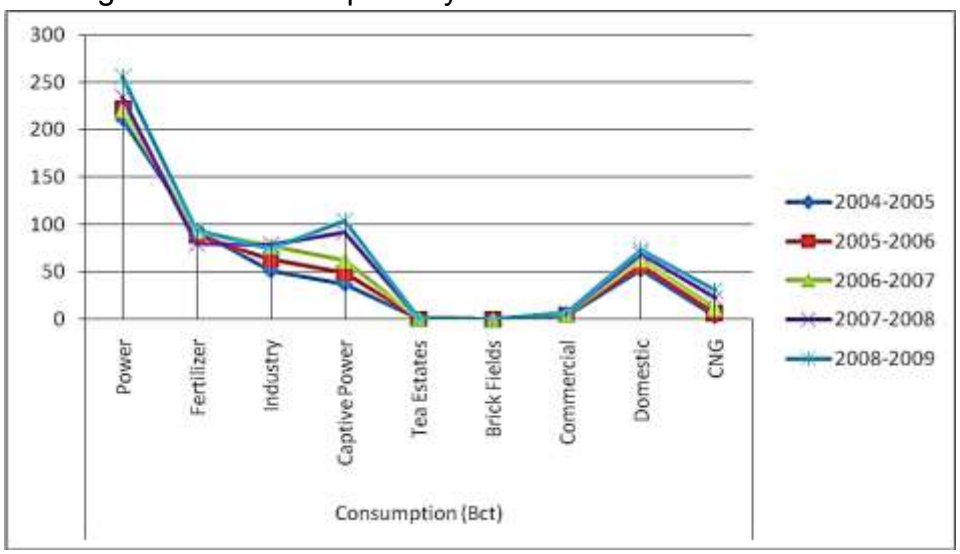
Since the discovery of the first well at Sylhet in 1955, a total number of 23 gas fields have been explored successfully. It is seen that about 2000 Million of Cubic feet per day (MMCFD) is produced from these fields (UNDP, 2011).

Table 1: Natural Gas sector (2004-2009)	
Total number of gas fields	23
Number of producing gas fields	17 (79 wells)
Extractable gas reserves (proven and probable)	20.5 TCF
Total consumption of gas up to A2010	8.5 TCF
Total reserve remaining	12 TCF
Daily gas production	2000 MMCFD (approx.)

Source: Energy and Mineral Resources Division, 2010

Natural gas is the most significant source of commercial energy. The gas consumption rate in Bangladesh is increasing day by day with the increasing population of the country.

Fig 1: Gas Consumption by different sectors 2004-2009



Source: Energy & Mineral Resources Division, 2010

Even as recently as a decade ago all of Bangladesh's coal needs were met from imports. Since 2005, about 1.8 million coals are being mined at Barapukuria. About 2355 million of coal deposits have been discovered in five locations in northern Bangladesh. Total peat reserves in Bangladesh are estimated at about 600 million tons. In some rural areas locally extracted peat is used for domestic cooking and in small industries.

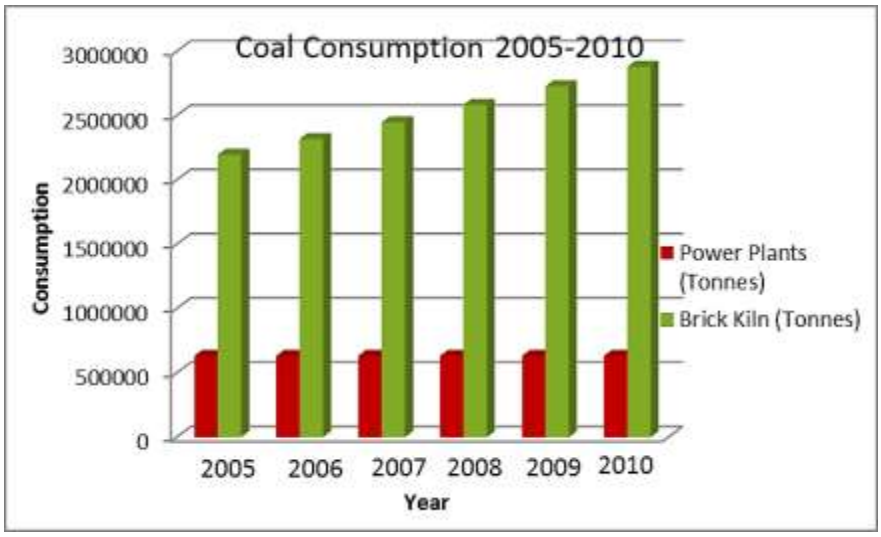
Table 2: Location of different mineral resources location

Location & Year of Discovery	Depth (Meter)	Mine area (sq.km.)	Estimated Reserves (Million Ton)
Boropukuria, Dinajpur (1985)	119-506	6.88	390
Khalashpur, Rangpur (1995)	257-483	12	143 (GSB)
Fhulbari, Dinajpur (1997)	150-240	30	572
Jamalganj, Bogura (1965)	900-1000	16	1050
Dighipara, Dinajpur (1995)	327	Not Available	200 (Partial Evaluation)

Source: Energy and Mineral Resources Division, 2010

Up to 2005 the demand for coal was for manufacturing bricks but later with the diversification of knowledge others means of using coal was discovered.

Fig 2: Demand for coal consumption 2005-2010



4.1.4 Transport

With continued economic growth and development, Dhaka, the capital of Bangladesh is beginning to experience massive traffic congestion. Today, this is causing extreme frustration to the inhabitants of the metropolitan which is the largest and most crowded city of the nation. The problems found in the transport sector of Bangladesh that major emphasis on private transport, a little amount of carpooling, low rate of cycling and walking, focused on fossil fuel powered transport & low transport interconnection.

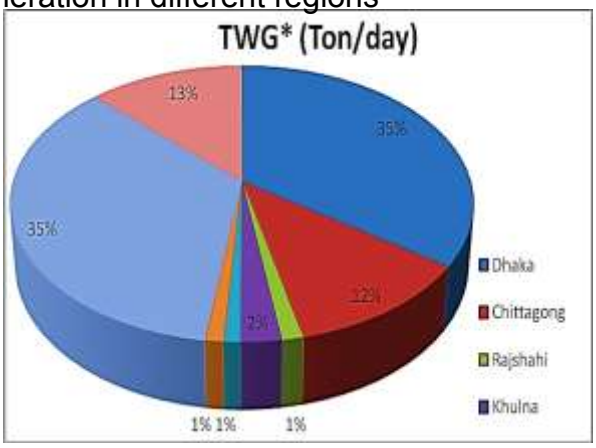
4.1.5 Waste generation

Total number of urban areas in Bangladesh is 514, which includes 11 City Corporations, 311 Pourashavas (Municipalities) (MAB, 2012) and 210 other urban centres. In order to estimate the total waste generated in these areas, each of the City Corporations, all Pourashavas and all urban centres are considered separately for different per capita waste generation rates. The total waste generation rate is estimated considering individual waste generation rates of the city corporations, an average for all the pourashavas and another average for all other urban centres.

Table & fig 3: Rate of waste generation in different regions

City/ Town	WGR* (kg/cap/day)	TWG* (Ton/day)
Dhaka	0.56	4,634.52
Chittagong	0.48	1,548.09
Rajshahi	0.3	172.83
Khulna	0.27	321.26
Barisal	0.25	134.38
Sylhet	0.30	142.76
Pourashava	0.25	4,678.40
Other Urban Centre	0.15	1,700.65
Total	Avg. 0.41	13,332.89

Source: West Concern, 2009



From the table it is seen that total waste generated in the urban areas of Bangladesh per day is 13,332.89 tons. Based on the total estimated urban population of the year 2005, per capita waste generation rate is computed as 0.41 kg/capita/day.

Table 4: Situation of wastes in Bangladesh

Type	Statistics	Source of data
TOTAL VOLUME OF WASTES (tons/year)		
Total volume of municipal solid wastes in urban areas	4,866,505 (2005) = 13,332.89tons/day x 365 3,000 tons/day in Dhaka (2005)	Waste Concern (2005) JICA (2005)
Agricultural Waste	65 million metric ton per year	Waste Concern and Swiss Contact 200
Industrial waste	109.47 million/cubic meter/year (waste water) 0.113 million ton/year (sludge) and 26, 884 tons/year (solid waste)	Waste Concern and ADB (2008)
Hazardous Medical Waste	12,271 metric ton per year (2007)	West Concern & ADB (2008)
WASTE PER CAPITA (kg/per/day)		
	Urban: 0.41 (2005) Dhaka City: 0.56 (2005) Agricultural:1.68 (based on 2008 rural population)	Waste Concern (2008) JICA (2005)
FUTURE WASTE PROJECTIONS (Total Waste Generation)		

Type	Statistics	Source of data
By 2025 (solid waste) 2012 (hazardous waste)	17,155,000 tons/year = 47,000tons/day x 365 0.60 kg/per/day in Urban Areas 2472.07 million/cubic meter/year (waste water), 2.81 million metric ton/year (sludge) and 53,874 metric ton/year (solid waste)	UMP (1999), as cited by Waste Concern (2008) Waste Concern and ADB (2008)
TOTAL VOLUME OF WASTES (tons/year)		
SOLID WASTE MANAGEMENT		
Collection of waste (% of waste generated)	44.30% - 76.47% in major urban cities	Waste Concern (2005)
E-WASTES: Use of electronic goods in year 2006	Mobile phones: 22,000,000 units Personal computers: 600,000 units Televisions: 1,252,000 units	Waste Concern (2008)
RECYCLE: Informal Sector	120,000 urban poor from the informal sector are involved in the recycling trade chain of Dhaka City.15% of the total generated waste in Dhaka (mainly inorganic) amounting to 475 tons/day are recycled daily.	Waste Concern (2005)

4.2 Waste Recycling:

Informal sector is playing an important role in Bangladesh in recycling of solid wastes. The existence of waste, mainly inorganic, has opened quite an extensive scope for various groups of the community to utilize it profitably. Informal sector is also playing a prominent role in collection of recyclable materials. All the buyers of the recyclable items belong to the informal sector and only a few formal manufacturers are involved in using recyclable items as raw material. Although recycling of solid waste is not included in the national environmental policy, waste has become the main source of income for several groups of the informal sector.

Table 5: Waste Recycling Scenario of different regions

City/ Town	TWG* (Ton/day)	No. of City/ Town	% of inorganic Waste Recycling	Savings through recycling per year (Tk. Million)
Dhaka	4,634.52	1	15.00	170.00
Chittagong	1,548.09	1	12.45	28.96
Rajshahi	172.83	1	6.7	1.00
Khulna	321.26	1	6.00	6.94
Barisal	134.38	1	5.42	5.14
Sylhet	142.76	1	4.23	3.44
Pourashava	4,678.40	298	3.89	8,862.52
Other Urban Centre	1,700.65	210	4.00	1,627.50
Total	13,332.89	514		10,705.5

TWG*= Total Waste Generation, Source: JCA 2004, Chittagong City Corporation, Field Survey (2000), Sylhet City Corporation.(Iftekhar Enayetullah, 2005)

Fig 4:Waste Recyling Practices in different regions

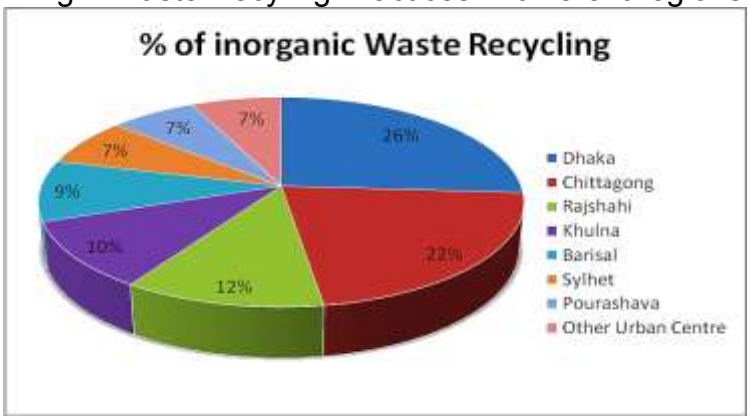


Table 6: Waste generation rate and projection

Year	Urban Population	Total Urban Waste Generation (Ton/day)	Per Capita Waste Generation Rate in urban areas Kg/cap/day	Per Capita GDP
1991	20.8 million	6493	0.31*	US $ 220
2005	32.76 million	13,332	0.41**	US $ 482***
2025	78.44 million	47,00	0.60***	

Data source: * World Bank, 1998, *** Waste Concern, 2005, *** UMP, 1999, **** GOB, 2006

4.3 Policy Measures to address the Metobolic Practices

Different policy measures have been taken by the government of Bangladesh over the years to develop the overall metabolic condition of the cities as well as of the country. However, due to lack of organized and focused efforts with the line of ensuring the sustainable metabolism practices the overall process of management has been failed. In the following different policies, acts, rules and actions concerning the metabolic approaches at different level are addressed here.

Table 7: Legal Issues related to resources consumption in Bangladesh

Year	**Title**
	Policy
2006	Draft National Urban Policy • CDM and Recycling has been emphasized in this policy.
2008	National Renewable Energy Policy • This policy is promoting production of biogas and other green energy from waste and also providing incentives such CDM to promote green energy projects.
1999	National Agriculture Policy • According to this policy the government will promote use compost/organic fertilizer amongst the farmers to improve the soil productivity and food security

Year	Title
2005	National Industrial Policy • This policy is recommended use of EMS (Environmental Management System) and Cleaner Production practices amongst the industries
1998	National Policy for Water Supply and Sanitation • According to this policy the government shall take measures for recycling of waste as much as possible and use organic waste materials for compost and bio-gas production.
1998	Urban Management Policy • Statement Recommend the municipalities for privatization of services as well as giving priority to facilities for slum dwellers including provisions of water supply, sanitation and solid waste disposal.
	Acts
2006	Fertilizer Act • Under this act compost has been promoted and standard of compost has been set by the government on 2008.
1995	Bangladesh Environmental Conservation Act (ECA) • Recommends standards for disposal of different types of waste.
	Rules
2008	Biomedical Waste Management Rules. • This rule recommends source separation of hospital waste as well as separate collection, transportation and treatment and disposal of all kinds of hospital and clinical waste
2006	Lead Acid Battery Recycling and Management Rules • Under this rules collection and recycling has been improved.
2005/ 2010	Draft National Solid Waste Management Handling • Rule 3R principle has been used.
1997	Bangladesh Environmental Conservation Rules (ECR) • Recommends waste disposal standards for mainly industrial wastes.
	Strategy
2005	National CDM (Comprehensive Disaster Management) Strategy • This strategy is promoting pro-poor CDM projects on waste sector by harnessing carbon financing.
2005	Poverty Reduction Strategy Paper (PRSP) • Here EMS has been promoted. To improve the solid waste management situation, special focus is given to segregation of waste at source along with the promotion of recycle, reduce and reuse of industrial and other solid waste etc.
2005	National Sanitation Strategy • Its goal is to achieve 100% sanitation coverage by 2010. Here emphasis on resource recovery and recycling has been given as top priority to improve urban sanitation situation instead of disposal.
	Action Plan
2005	Dhaka Environment Management Plan • Waste recycling has been promoted, less land filling encouraged, EMS promoted among industries.

Year	Title
2005	Solid Waste Management Action Plan for Eight Secondary Towns in Bangladesh • Under the Secondary Towns Integrated Flood Protection (Phase-2) Project of Local Government Engineering Department, GoB. This action plan is based on 4 R principle i.e. reduce, reuse, recycle and recover of the waste.
1995	National Environmental Management Action Plan (NEMAP) • This is a plan of the Government of Bangladesh (GoB), prepared by the Ministry of Environment and Forest (MoEF) in consultation with people from all walks of life. 3R is being promoted under the Sustainable Environment Management Program (SEMP) of NEMAP.
Other	
2008	Circular to Promote Compost by the Ministry of Agriculture (MoA) • on 23 April 2008 Ministry of agriculture issued a circular to promote use of compost amongst the farmers to reduce the burden
2004	Private Sector Infrastructure Guideline • This guideline of the GOB has recommended private sector investment in waste management sector which includes all types of waste. It has also identified waste sector as one of the priority sector for private investment
2005	Private Sector Housing Development Guideline • This guideline recommends to space in new housing areas for waste recycling specially composting and bio gas generation.
2004	Dhaka Declaration on Waste Management by SAARC • Countries during 10–12 October 2004 SAARC countries agree to encourage NGOs and private companies to establish community based composting, segregation of waste at source, separate collection and resource recovery from wastes with particular focus on composting.
Source: Second draft report on National 3R Strategy for Waste Management, West concern, 2009	

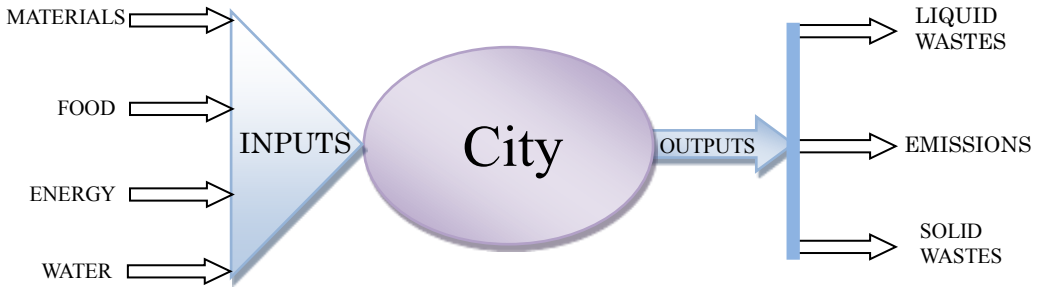
It is evidenced that the Government of Bangladesh has developed and adopted different policies, actions and rules according to need and case basis. However, the sustainable metabolic process should be explored as a comprehensive system of all input and outputs of materials at different functional systems of the city in an economic setup.

4.4 Findings- Bangladesh's Practices and Learning from European Strategies

Analyzing the overall metabolic condition and relevant policies, acts, rules and actions of Bangladesh the overall deficiencies of the resource consumption, use and their management have been identified. It is observed that the management approach in Bangladesh is following the linear system of metabolism. The metabolic analysis of Bangladesh shows that the haphazard uses of resources without the comprehensive system of policies and tools. Though different policies have been taken, those policies are practicing at small scale and at private level in a limited way. The Government

concern about the facts and policies is relatively low. In Bangladesh mostly the linear metabolic relation is practicing. Linear metabolism system has also other drawbacks and adverse environmental impacts. For instance, water use in the linear system withdraws excessive volumes of water from the surface and groundwater resources, the urban streams for long distances, including the urban sections, have insufficient or no flow. In the figure5 the hypothetical representation of Bangladesh's metabolic practices are show.

Fig 5: Linear Metabolic Relation of cities of Bangladesh



On the other hand, it is found from the different case studies that European countries have moved to cyclic metabolic relations from linear metabolic relations. As a part of ensuring the circular metabolic system European countries are practicing the following principles under a comprehensive scheme. .

Table 8: Present and Sustainable situation comparison

Present Condition ⇒ Sustainability

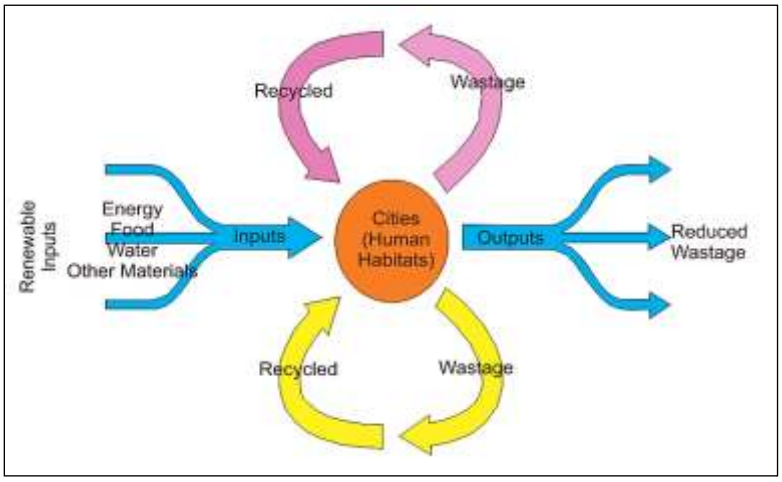
Resources		
Food	Agriculture Based Economy	Agriculture & Industry Based
	Monopolistic Food Pattern	Diversified Food Pattern
	Low Rate of Conservation	High Facilitated Conservation System
	Low investment on food production	Well distributed investment on food production.
Water/ sewage	Imbalanced consumption of water.	Well distributed water supply.
	Water extraction exceeding recharge	Balanced water extraction and ground recharge.
	Single household water system.	Low flush toilets as norm. Malty household water systems.
	No run-off storage.	Substantial run-off storage.
	Little sewage recycling.	Routine sewage recycling.
Energy	High dependency on natural resources i.e. natural gas, coal etc.	More utilization of renewable energy i.e. wind turbine, hydraulic power plants etc.
	Major usages of gasoline, fossil fuels etc.	Solar/ wind/ biomass & fuel cells as main energy technologies.
Transport	Emphasis on private transport.	Optimal transport mix.

	Minimal car sharing.	Widespread vehicle sharing.
	Little cycling and walking.	'Urban village', cycling and walking.
	Fossil fuel powered transport.	Fuel cell & solar-electric transport.
	Low transport interconnection.	Optimal interconnections.
Wastes	Most waste disposed in landfills Some incineration. No remanufacturing.	Remanufacture of metals, glass, Paper & consumer waste into new products has become routine.
	Low rate of recycling	High rate of recycling
	Involvement of informal sectors	High involvement of government & private farms
	Linear system	Circular or Cyclic System

5. Conclusion and Recommendations

Urban metabolism is a widely accepted practice all around the world nowadays. Analyzing the metabolic practice and its sustainability will pave the way towards a better future for the developing world. This system already benefited the European countries; application of the similar patterns might help the development process of the developing countries towards a sustainable one. Circular metabolic system might be a solution for Bangladesh to attain metabolic sustainability. The figure6 gives a hypothetical idea of circular metabolic system.

Fig 6: Recommended Metabolic Relation for Bangladesh



Different cities have already applied this circular metabolic approach for reducing the amount of wastes. For Example, the City of Oakland, California, set a goal of Zero Waste in its 2006 strategic plan, effectively changing a linear metabolism into a circular approach by initiating comprehensive policy frameworks. The first step in this city of 400,000 residents was to reduce the annual tonnage to landfill from 400,000 tonnes to 291,000 tonnes in four years by returning waste materials to the local economy for reuse and recycling, applying the reduce, reuse, recycle and compost waste hierarchy.
In case of Bangladesh circular metabolic approaches can also be a suitable solution to attain metabolic sustainability. The existing policies, rules and acts should also be modified under this umbrella approach. Different induced challenges such as challenges of climate change, environmental pollution due to industrialization, natural hazards etc.

should be considered to develop the framework of metabolic approaches at city level. City planning and development control tools should also be considered during the formation and practices of the metabolic approaches at city level.

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