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Low-Carbon Development (LCD) Pathways in Australia, Bangladesh, China and India—A Review

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Abstract: The low-carbon development (LCD) is the development that causes low greenhouse gases (GHGs) emission, reduce vulnerabilities of climate change impacts on social, economic, environmental sectors/assets and integrate/incorporate climate change as a risk in development programmes. This article identified that there are multiple concepts of LCD in different countries and the international communities. It highlighted that improvements in energy efficiency and energy conservation, investments/increased use of low carbon or green energy (renewable energy), switching to low-carbon transport, carbon capture and storage, reducing the carbon footprint of an organisation etc. are essential achieving LCD. The article emphasised LCD in the natural and human-built environment including agriculture, buildings/infrastructure, fisheries & aquaculture, forestry, industry, power/energy, tourism, transport, water and wastes.

There are several initiatives, strategies, policies and actions on LCD in Australia, Bangladesh, China and India. Those are awareness, education, capacity building and behaviour changes of communities on LCD; targets of capping green and renewable energy for short-, mid- and long-terms; zero tillage, climate smart agriculture, agroforestry; use of energy efficient appliances, afforestation/reforestation/restoration of forests; use of low carbon power (solar, wind, nuclear, hydro, biofuels); energy production from organic waste; zero waste, zero carbon emissions; sustainable consumption; carbon capture and storage; carbon tax; low-carbon/green cities; low-carbon transport; investment in low-carbon technologies; rainwater harvesting, R&D and innovation and subsidies on solar heaters, electric vehicles and energy efficient appliances. Australia, China, Bangladesh and India have set up a future target for renewable energy (RE) of 20%, 15%, 10% and 35% respectively. Low-carbon energy consumption has been significantly higher in China and India, for example, RE, hydro and nuclear power consumption was highest in China, whereas biofuels in India. Australia and Bangladesh do not produce nuclear power. The community lifestyle and behaviour changes have been identified as an important pathway to achieve LCD. LCD discussed in this article falls within the scope of several newly globally agreed sustainable development goals. Courses should be introduced at local schools, colleges and universities so that people can understand and be equipped with tools and technology related to LCD.

Keywords: Low-carbon development; Greenhouse gases; Carbon footprint; Renewable energy; Australia, Bangladesh, China, India.

Introduction

The low-carbon development (LCD) can be defined as development that causes low greenhouse gases (GHGs) emission, reduce vulnerabilities of climate change impacts on social, economic, environmental sectors/assets and integrate/incorporate climate change as a risk in development programmes (note: low carbon

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= low greenhouse gas). LCD is based on low power consumption, low pollution, low GHG emissions and efficient use of energy in all sectors including agriculture, buildings, industry, power, water and transport (Figure 1). In China, the National Development and Reform Commission (NDRC) describes LCD as the development of the socio-economic system that can realize low carbon emissions, whereas India's National Action Plan on Climate Change (NAPCC) highlights the co-benefits approach for low carbon activities that could, in turn, ensure energy security, reduced local pollution, and increased access to energy through distributed and decentralized forms of energy systems (GoI, 2008). LCD would help protect the earth's ecology and human survival and development, and the voluntary cooperative acts of all parties to protect the common interests of all mankind (He, 2016).

LCD concepts are used differently in different countries and the international communities. They are (i) *Low-carbon development* (China, Europe, Guyana, Singapore, United Nations Environment Programme, World Bank); (ii) *Low-carbon economy* (Australia, China, European Union, Intergovernmental Panel on Climate Change, Renewable Energy and Energy Efficiency Partnership, USA); (iii) *Low-carbon society* (Finland, Japan, UK); (iv) *Low-carbon city* (China, Japan); (v) *Low-carbon community* (Australia, Japan, UK); (vi) *Low-carbon life* (China, Singapore) (Yuan et al., 2011); (vii) *Deep decarbonisation* (Australia, Brazil, Canada, China, France, Germany, Japan, India, Indonesia, Italy, Mexico, South Africa, South Korea, the United Kingdom, the United States of America) (DDPP, 2015) (*Note:* Deep decarbonisation is referred to as deep cut of GHG emissions to promote a low- carbon world in order to limit a global temperature rise of 2°C).

LCD is a new pattern of political and socio-economic development aiming at reducing CO_2 emissions including other GHGs and achieving new global sustainable development goals (SDGs) and targets. It aims to reduce GHG emissions consistent with the <2°C limit rise in temperature (as agreed in Paris Conference in December 2015) while accommodating the expected economic and population growth.

Objectives

The main objectives of this research are to:

- Identify pathways to achieve LCD in economic, social and environmental sectors.
- Review LCD initiatives, strategies, policies and actions programmes and plans in Australia, Bangladesh, China and India (viz. awareness, education, capacity building and behaviour changes of communities on LCD; targets of capping green and renewable energy for short-, mid- and long-terms; zero tillage, climate smart agriculture, agro-forestry; use of energy efficient appliances, afforestation/reforestation/restoration of forests; use of low carbon power (solar, wind, nuclear, hydro, biofuels); energy production from organic waste; zero waste, zero carbon emissions; sustainable consumption; carbon capture and storage; carbon tax; low-carbon/green cities; low-carbon transport; investment in low-carbon technologies; rainwater harvesting; R&D and innovation and subsidies on solar heaters, electric vehicles, energy efficient appliances).
- Review community lifestyle and behavioural change pathways to achieve LCD.
- Review the relationships between sustainable development goals (SDGs) and LCD.
- Evaluate pathways of the success of LCD.

Pathways to LCD

The pathways to achieve LCD lies with energy system transformation such as (a) improvements in energy efficiency and energy conservation in all sectors (Figure 1a); (b) investments/increase use of low-carbon energy (renewable energy/clean energy such as solar, wind, hydro, biogas, pumped hydro) (Figure 1b); (c) switching to low-carbon fuel in transport, buildings, industry (Figure 1c); (d) reducing non-energy emissions via reforestation, carbon offsets and carbon capture and storage (Figure 1d); and other measures including reducing the carbon footprints of an organisation, pursuing a simple low-carbon lifestyle of community, adopting low-carbon manufacturing and advocating the low-carbon consumption patterns (DDPP, 2015; ClimateWorks Australia, 2010 and 2014) (*Note:* GHG emissions from fossil fuels such as coal is 955 CO_2 g/kWh compared to 98-167 CO_2 g/kWh from solar photovoltaic and much lesser from hydro- and wind- 3.6-11.6 and 7-9 CO_2 g/kWh respectively (Akella et al., 2009).

Pathways to Achieve LCD in Economic, Social and Environmental Sectors

The principles of LCD in achieving sustainable development goals and reducing GHG emissions and limiting the rise in global temperatures below 2°C

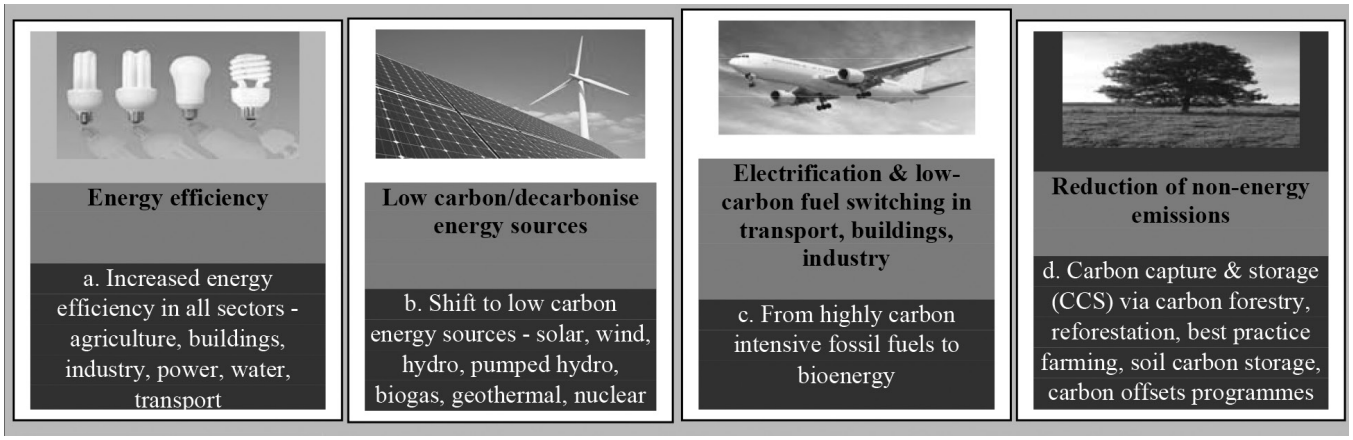

Figure 1: Pathways to low-carbon development.

(Consult Table 1. Australia, Bangladesh, China and India have identified that energy efficiency, low-carbon energy, low-carbon transport, carbon capture & storage, afforestation/reforestation, carbon offsets strategies etc. are important to achieve LCD)

as per Paris Climate Agreement can be applied in different social, economic and environmental sectors as highlighted below:

Agriculture

Reduce or no-tillage agriculture (to prevent soil carbon loss and soil carbon sequestration through storage of soil organic matter); improved livestock feeding (to reduce CH_4 emissions); manure management and efficient use of fertilisers (to reduce emissions of N_2O); alternate wetting and drying in rice cultivation (to reduce emissions of CH_4); agroforestry (to enhance carbon stock), energy efficient aquaculture (oysters, seaweeds, herbivorous fish that require less energy inputs to grow); aqua-silviculture (integrating aquaculture with mangrove to sequester carbon); integrated agriculture-aquaculture (to recycle wastes and to be more energy and resource efficient farming); use of renewable energy in irrigation water delivery (Kibria et al., 2013; Kibria et al., 2017b) (see also Table 1).

Buildings/Infrastructure

Replacing energy inefficient light bulbs; retrofit with energy and water efficient appliances; replacing electric heaters with gas/solar powered water heaters; LED lighting; high efficiency electric appliances; insulation; smart urban designs; switching from highly carbon-intensive fossil fuels to low carbon electricity; rooftop solar PV; double glazing of windows; building of low-carbon/zero carbon homes with green roofs to reduce urban heat islands effects (DDPP, 2015; ClimateWorks Australia, 2010) (see also Table 1).

Ecosystems

Conserving wetlands/forest habitats (which are biodiversity 'hot spots', and act as major carbon sinks); preserving existing and intact floodplain rivers; provision/allocation of environmental water for wetlands to be affected by droughts; and increase awareness education to safeguard native fish, wildlife, and plants (Kibria and Haroon, 2017) (see also Table 1).

Fisheries and Aquaculture

Promotion of climate-smart fisheries/fishing (e.g. use of energy efficient vessels, fish waste recycling to produce organic fertilisers, pelagic trawling rather than bottom trawling), climate-smart aquaculture/energy efficient aquaculture (e.g. cultivation of oysters, seaweeds, herbivorous fish, integration of aquaculture with mangrove) and conservation of seagrass and seaweed beds, salt marshes, and mangroves (which acts as carbon sinks and mitigate the impacts of climate change via photosynthesis and carbon sequestration/sinks in sediments) and conservation of calcifying organisms (e.g. reef-building corals, invertebrates, and shell-fishes which would contribute to calcium carbonate deposits and act as oceanic carbon sinks) (Kibria et al., 2017a) (see also Table 1).

Forestry

Reduce deforestation; planting farmland with trees, planting trees along waterways, carbon storage into the soil and vegetation through afforestation/reforestation/mangrove restoration (Kibria et al., 2013; Kibria et al., 2016) (see also Table 1).

Table 1: Low-carbon development (LCD) initiatives, policies, strategies, actions in Australia, Bangladesh, China and India

Australia	*Bangladesh*	*China*	*India*
Agriculture: efficient use of fertilisers; zero tillage to reduce cropland soil carbon loss; reduce livestock methane emissions; reduce/ avoid burning of residue; use improved crop varieties to retain more soil carbon; manage/restore pasture and natural grassland to reduce emissions and increase soil carbon; re-vegetation; enhance cropland carbon sequestration; reduce deforestation (CWA, 2010). **Awareness, education and behaviour change:** educate the community with better information on LCD, purchasing energy efficient appliances and vehicles; carpooling, low-carbon lifestyle (CWA, 2010). **Buildings:** retrofit with energy efficient appliances (e.g. light bulbs, refrigerators, heaters) in new and old buildings; reduce or save energy and water (CWA, 2010); high-efficiency building materials (Troy, 2016); zero energy house. **Forestry:** reforestation; carbon forestry; reduce deforestation, improve forest management via removal of weeds such as blackberry, lantana; control feral animals, insects, pests (CWA, 2010).	**Agriculture:** promote low emission agriculture farming practices (Khan, 2013); promote climate-smart/energy efficient agriculture, aquaculture; reduce GHG (methane) from rice fields, livestock (Kibria et al., 2017). **Awareness education:** introduce awareness education on energy efficiency, energy saving/ conservation and solar energy in the curricula of schools, madrasas and colleges and community institutions (Khan, 2013), introduce LCD courses in schools, colleges, community & vocational institutes, and universities (Kibria et al., 2017b). **Buildings:** install solar panels in government, semi- government and autonomous organisations (Khan, 2013); limit the use of air conditioners (Khan, 2013).	**Agriculture:** establish emissions reduction through the sequestration of carbon in forests and agriculture soil (CCICE, 2009) and establish an agriculture-forestry system (agroforestry) (CCICE, 2009); promote sustainable agriculture (CCICE, 2009). **Awareness, education and behaviour change:** plan and implement education and training program model for LCD (at schools, communities, companies, family education), including low-carbon consumption/green consumption, low-carbon lifestyle, purchasing low-carbon goods, car-pooling, use of public transport, sustainable consumption, sustainable procurement, calculating carbon footprint and green information sharing with community (CCICE, 2009; Wang, 2009). **Buildings:** implement energy efficiency in buildings (CCICE, 2009); introduce energy efficiency standards and labelling systems (CCICE, 2009). **Carbon capture and storage:** implement carbon capture and storage (CCICE, 2009). **Carbon footprint:** introduce a "carbon footprint" labelling system on products to encourage the public for buying and consuming low carbon products (CCICE, 2009). **Carbon sequestration:** increase carbon sequestration in arable land, forests and grasslands (CCICE, 2009). **Carbon tax:** implement a carbon tax, the revenue of which should be utilised for low carbon innovation (CCICE, 2009; Zhu et al., 2013). **Carbon trading:** establish a voluntary carbon trading scheme (emission reduction against baseline year) with appropriate subsidies or loan support to encourage firms to carry out voluntary emissions reductions (CCICE, 2009). **Cities:** ensure compact urbanization, as compact cities have lower emissions (CCICE, 2009); launch low-carbon urban development in cities via energy-savings in the transport and building sectors, and promoting low or zero-carbon communities and ecological cities) (CCICE, 2009). **Consumption:** implement policies to reduce the total primary energy consumption and improve the proportion of renewable energy as part of the CO_2 emission reduction, resource saving and mitigating climate change effects (He, 2016).	**Agriculture:** promote 'no-tillage' agriculture; promote and organic farming; promote the use of bio-fertilisers; change/ modify nutritional regime in cattle to reduce enteric fermentation; promote agroforestry; enhance capacity building of farmers in latest rice cropping techniques; promote integrated pest management; adopt water-efficient practices, use low water requiring crops; promote sewage fed fisheries (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Awareness, education and behaviour change:** enhance capacity building of different industries on carbon and water footprints, climate change; promote capacity buildings of communities/ on forest management, solid waste management; develop curriculum on energy efficiency and renewable energy and applications in schools (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Banking provisions:** special provisions for MSME (Ministry of Micro, Small and Medium Enterprises) & priority sector lending norms by the Reserve Bank of India to finance renewable energy projects (Kedia and Jain, 2015). **Buildings:** promote energy efficient housing, household appliances; green buildings concept; and use of solar energy in housing (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Carbon capture & storage:** implement carbon capture and sequestration (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Certificate:** implement energy saving certificates to encourage the community

(*Contd.*)

Industry: enhance energy efficiency; use energy efficient appliances; reduce oversized equipment, upgrade motor systems; decrease energy losses in boilers and steam distribution systems (CWA, 2010).

Investment: invest in renewable power-including onshore wind, solar, geothermal (CWA, 2010; GoSA, 2015).

Lighting: replace the compact fluorescent lamp with LEDs, replace inefficient T12s or T8s (T12 are energy inefficient fluorescent tube lights) with new super T8s and T5s (T8, T5 are very energy efficient fluorescent tube lights and smaller in size compared to T12) (CWA, 2010).

Power: promote low carbon and renewable energy generation (GoSA, 2015); carbon capture and storage (CCS) (CWA, 2010; http://www.2050pathways.net.au/; shift from coal to gas; improve coal and gas power plant thermal efficiencies; reduce transmission and distribution loss- larger capacity conductors (CWA, 2010); transform waste into energy-biogas (LCAL, 2013).

Forestry: invest in carbon sink project such as afforestation/reforestation/mangrove restoration (Kibria et. al., 2017b).

Industry: introduce low carbon technology in high carbon emitting sectors such as brick baking kilns (Khan, 2013).

Investment: invest in energy efficiency, renewable energy (solar home system; biogas plant for cooking gas; solar mini-grid; solar irrigation pump; biogas-based power plant; biomass-based power plant), invest in energy efficiency labelling and standards and waste to energy projects (Khan, 2013; Kibria et al. 2017b; UNDP, 2017); invest in electricity generation from solar PV systems for street lighting, solar lanterns, bioenergy (using rice husks) and biogas from organic waste plants (UNDP, 2017).

Decarbonization: implement programme to conserve natural resources and energy, recycling of waste resources and clean, efficient use of energy as part of decarbonization (He, 2016).

Eco-civilization: incorporate the concept of eco-civilization into the overall strategic plan to protect the nature, ecological environment, and low-carbon development (He, 2016).

Energy law: implement and reform energy saving law, renewable energy law to further encourage the development and use of clean, low carbon energy sources (CCICE, 2009).

Energy savings: promote energy saving, improve energy efficiency and reduce energy consumption (CCICE, 2009; Wang, 2009; Du, 2016; Jiang et al., 2016; He, 2016).

Forestry: increase the forest stock volume by around 4.5 billion m^3 on the 2005 level by 2030) (Kedia, 2016); emissions reduction through the sequestration of carbon in forests and soil (CCICE, 2009); increase carbon sequestration in forests and grasslands; reduce grazing density in grasslands and plant new areas with natives (CCICE, 2009).

Green credits: establish and implement the green credit policy for energy saving, emission reduction and environmental management (Kedia, 2016).

Greenization: implement greenization as part of decarbonization, control of traditional pollutants, GHGs and global warming and sustainable economic and social development.

Investment: investment in low-carbon technologies (Table 3) including energy supply and energy efficiency improvement; energy saving in transportation (energy saving vehicles, locomotives, vessels and subway; investment in renewable energy (RE) supply sector (hydro-power; nuclear power; wind power; solar power, biomass power); investment in energy saving in manufacturing (steel, glass, non-ferrous, chemical, boiler, electric motor), investment in energy saving in buildings (new and old) (Du, 2016; Jiang et al., 2016); invest in low carbon buildings (CCICE, 2009).

Low carbon development (LCD) paths: explore and establish the green and low-carbon development goals & paths, establish RE and GHG emissions reduction targets and action plans (He, 2016); launch low-carbon urban development in suitable cities to achieve energy-savings in the transport and building sectors, and to promote low or zero-carbon communities and ecological cities (CCICE, 2009).

to adopt to a low-carbon lifestyle (Kedia, 2016).

Cities: promote green city concept; bus rapid transit (BRT); promote non-motorized transport; climate-responsible master plans for cities/town; promote renewable energy usage in the urban sector, e.g. solar water heating and lighting; promote mass construction of rooftop rainwater harvesting structures in urban areas (Teri-Ncsc-Cufe- Zu-UNDP, 2014).

Climate funds: implement innovative financing for LCD via green climate fund, adaptation fund; national clean energy fund, state energy conservation fund, IREDA fund (Indian Renewable Energy Development Agency); sub-national funds (Kedia and Jain, 2015).

Coal cess/carbon tax: implement coal cess to finance and promote clean environment initiatives (Kedia and Jain, 2015).

Forestry: create additional carbon sink of 2.5-3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030 (Kedia, 2016); implement forest fire management; integrated afforestation/reforestation and eco-development project; reduce forest fragmentation by conserving contiguous forest patches; promote agroforestry; restore the degraded forest, plant new mangrove belts across the coast; promote sustainable ecotourism; regulate grazing in native grasslands; connecting fragmented forests with 'corridors' to assist species migration (Teri-Ncsc-Cufe- Zu-UNDP, 2014).

Infrastructure: promote climate sensitive architectural urban infrastructures (Teri-Ncsc-Cufe- Zu-UNDP, 2014).

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Table 1: (*Contd.*)

Australia	*Bangladesh*	*China*	*India*
Research: carry out R&D on energy storage, low-carbon technologies (Table 3) and to improve knowledge on LCD (GoSA, 2015; http://www.2050pathways.net.au/). **Transport:** expansion of electric buses, trucks and cars (CWA, 2010; Troy, 2016); or hybrid vehicles; increased use of renewable biofuels in petrol or diesel engines (CWA, 2010); improved efficiency of the national freight and passenger transport systems (Troy, 2016); switch from fossil fuel to electricity (http://www.2050pathways.net.au/). **Water:** reduce water consumption; reduce 'wastewater' flows into the environment; use waste reclaimed water for biodiversity conservation (Troy, 2016). **Waste:** implementation of zero waste policy; improved utilisation of waste such as crop residues, manufacturing and processing residues, animal wastes, and residential and commercial organic waste, including sewage waste (GoSA, 2015).	**Lighting:** use compact fluorescent lamp (CFL) bulbs in all ministries and power sector entities; replace street lights by LED and solar lights (Khan, 2013). **Consumption:** provide incentives to promote the efficient production, consumption, distribution and use of energy (Khan, 2013). **Water:** conserve water and harvest rainwater (Kibria et al., 2017b).	**Low-carbon lifestyle:** implement the concept of green building, low-carbon travel, energy saving and carbon reduction as part of community behaviour change (He, 2016). **Low carbon provinces and cities:** implement a low carbon province and city program via low carbon industrial systems, low-carbon lifestyle, low-carbon consumption and low-carbon green growth (Kedia, 2016). **Low-carbon society:** plan and implement "resource-efficient, environment-friendly and low-carbon oriented" society (Wang, 2009). **Phase out:** phasing out inefficient industrial boilers (Zhu et al., 2013). **Power:** increase RE power such as wind, solar, hydropower, nuclear power (CCICE, 2009; Zhu et al., 2013; He, 2016), and reduce consumption of coal (CCICE, 2009). **R&D:** development of advanced energy technology (smart grid and energy storage technology, carbon capture and storage for sectors such as steel and cement); industrial energy-saving technologies and equipment (CCICE, 2009; Kedia, 2016). **Regulations:** implement policies to prevent the destruction of natural forests, natural grasslands; improve rules for solid waste management to reduce GHG emissions (CCICE, 2009). **Renewable energy:** vigorously develop new and renewable and green energy and increase non-fossil energy supply (Zhu et al., 2013; He, 2016), promote increased use of biofuel in transport, biomass in electricity generation, and biogas for heating (CCICE, 2009). **Transportation:** plan, and develop strategies for energy saving in aircraft (Jiang et al., 2016); promote public transport in cities including intra-city railways and expressways; mandatory fuel efficiency standards on conventional motor vehicles; promote/develop low-carbon transport (hybrid and electric vehicles), use of sustainable biofuels (CCICE, 2009); low carbon transport within urban areas as well as in the countryside (CCICE, 2009). **Targets:** implement a pollution control and GHG emission reduction target (Wang, 2009; He, 2016); 20% non-fossil fuels as primary energy consumption by 2030 (Kedia, 2016). **Zero CO_2 emissions:** establish a zero CO_2 emissions path via policies toward new and more renewable energy supply from wind, solar, hydropower, biomass, nuclear and R&D for advanced energy technology (development of smart grid and energy storage technology, carbon capture and storage) (He, 2016; Kedia, 2016).	**Investment:** make provision for additional investment for LCD (Kedia, 2016). **LCD:** implement LCD concepts in buildings, transport, agriculture, industry, waste and forestry (Kedia, 2016). **Power:** promote solar, wind, hydro, biomass, nuclear; geothermal and tidal energy; generate power from waste; R&D for new cleaner technologies; enhance efficiency in power generation (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Targets:** 40% cumulative electric power from non-fossil fuel based energy resources by 2030 (Kedia., 2016). **Tax rebate:** implement property tax rebates on green buildings (Kedia and Jain, 2015). **Transport:** bus rapid transit (BRT); promote non-motorized transport (walking and cycling), rail-based mass transit systems (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Subsidies:** implement subsidies on solar heaters, electric vehicles, energy efficient appliances (Kedia and Jain, 2015). **Waste management:** promote and innovate the use of waste for power generation (biogas); recover gas from landfill (Teri-Ncsc-Cufe- Zu-UNDP, 2014). **Water:** conserve water resources (wetland, lakes, rivers, indigenous ponds); harvest rainwater; manage waste water through reduce, reuse and recycle; develop models for urban stormwater flows; adopt water-efficient practices and use low water requiring crop (Teri-Ncsc-Cufe- Zu-UNDP, 2014).

Industry
Improve energy efficiency, carbon capture and storage and switching from highly carbon-intensive fossil fuels to low-carbon electricity and purchasing of green products/environmentally preferable procurement (ClimateWorks Australia, 2010 and 2014) (see also Table 1).

Power/energy
Investments in low-carbon electricity (wind, solar, biomass/biogas, hydro, geothermal, nuclear, pumped hydro); carbon capture and storage (CCS); and green tax/carbon price [ClimateWorks Australia, 2010 and 2014; WBCSD, 2012) (see also Table 1).

Tourism
Tourism revenue is one of the main sources of income in many countries; however, tourists are responsible for 4.4% of global CO_2 emissions (Xu and Liwen, 2011), awareness and education and encouragement of tourists for low carbon travel, low power consumption, energy efficiency, energy and water savings, recycling to reduce carbon emissions and reducing wastes to protect natural forests, wetlands, grasslands, mangroves and native flora, fauna, and cultural heritage sites (which are the primary tourists attractions) (Randall, 1987; Changbo and Jingjing, 2011) (see also Table 1).

Transport
Improve the fuel efficiency of petrol or diesel run cars, trucks, trains, aeroplanes and vessels; switching from highly carbon-intensive fossil fuels to low carbon electricity; improve energy efficiency in all energy end-use sectors including passenger and goods transportation, biofuels in aviation; high efficiency aircraft; road freight shift to gas; electric vehicles, hybrid vehicles; manufacture/use of smaller cars (ClimateWorks Australia, 2010, 2014) (Table 1).

Water
Rainwater harvesting, rain gardens; retrofitting homes with water-efficient toilets, showerheads, dishwashers, washing machines; use of renewable energy in water abstraction, treatment, end-use (Kibria et al., 2016) (see also Table 1).

Wastes
Reduce, reuse and recycle (3Rs) wastes; reduce food wastes (food waste contributes to increasing GHG emissions (methane) in landfills, therefore, process food waste to recover nutrients (as biofertilisers)); reduce plastic wastes (use of biodegradable plastic, curbing the growth of single-use plastics/plastic bags via ban, levy, tax on plastic bags); and reduce landfill GHG gas emissions via diverting waste from landfill; promote the use of biodegradable jute/gunny bags; produce biogas energy from wastes; promote food banks, food swap, food recycle, set up of reuse shop; recycling of food and garden wastes (Kibria, 2017a; Kibria, 2017b) (see also Table 1).

Case Studies: LCD Initiatives, Strategies, Policies and Action Programmes and Plans in Australia, Bangladesh, China and India

A review of LCD initiatives, strategies, policies and actions in Australia, Bangladesh, China and India reveals the following key facts (as shown below as dot points). These strategies, policies etc. are aimed to reduce GHG emissions and continue to have economic and social development in the country with minimum or nil impacts on the environment.

- Set up a target to produce renewable energy (RE) in the future; these targets ranged between 10% to 35%, for example, India set a target for RE of 35% by 2050 while Australia 20%, China 15% and Bangladesh 10% by 2020 (see Figure 2).
- There has been a trend of increased consumption of low-carbon energy such as RE, hydro, biofuels and nuclear power. Low-carbon energy consumption has been significantly higher in China and India. RE, hydro and nuclear power consumption was highest in China (see Table 2).

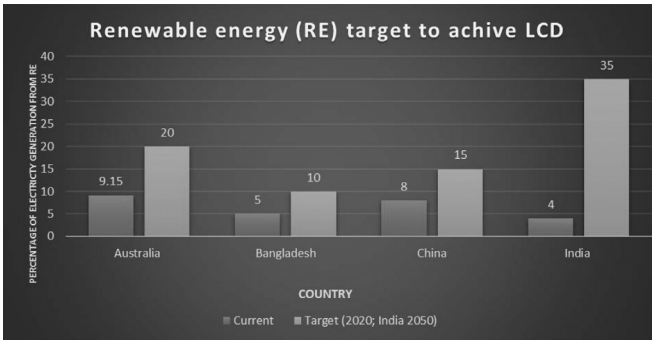

Figure 2: Renewable energy target in Australia, Bangladesh, China and India.

(data are based on Wikipedia 2015 and the following web links; http://www.irena.org/documentdownloads/publications/_pacificcomplete.pdf http://www.irena.org/DocumentDownloads/Publications/_AsiaComplete.pdf; https://cleantechnica.com/2014/07/16/india-targets-35-renewable-energy-share-installed-capacity-mix-2050/)

Table 2: Low-carbon energy consumption in selected developing and developed countries (Australia, Bangladesh, China and India)

Low-carbon fuel	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*Growth (2016 compared to 2010)*
Renewable (wind, solar, biomass, geothermal, waste) (million tonnes oil equivalent)								
Australia	1.9	2.5	3.0	3.7	4.1	4.8	5.4	184.2%
Bangladesh	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
China	15.9	22.8	29.4	42.3	50.8	64.4	86.1	441%
India	7.2	8.8	10.4	11.6	12.0	12.7	16.5	129.2%
Biofuels production (thousand tonnes oil equivalent)								
Australia	222	223	239	202	169	157	144	-35%
Bangladesh	-	-	-	-	-	-	-	-
China	1584	1970	2103	2346	2609	2653	2053	29.6%
India	123	210	229	268	349	410	505	310.6%
Hydroelectricity (million tonnes oil equivalent)								
Australia	3.1	4.4	3.9	4.3	3.3	3.2	4.0	29.03%
Bangladesh	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.0%
China	161.0	155.7	195.2	205.8	237.8	252.2	263.1	63.46%
India	24.6	29.8	26.2	26.2	31.5	30.2	29.1	18.29%
Nuclear (million tonnes oil equivalent)								
Australia	-	-	-	-	-	-	-	
Bangladesh	-	-	-	-	-	-	-	
China	16.7	19.5	22.0	25.3	30.0	38.6	48.2	188.62%
India	5.2	7.3	7.5	7.5	8.7	8.7	8.6	65.38%

Data are based on BP Statistical Review of World Energy June 2017 https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf

- The key initiatives, strategies, policies and actions on LCD in Australia, Bangladesh, China and India are summarised below; LCD strategies have been significantly developed and implemented in China and India (Table 1). They are: (i) Awareness, education, capacity building and behaviour change of communities (education related to LCD, low-carbon life style, low-carbon consumption, sustainable consumption); (ii) promote zero tillage, organic farming, climate smart agriculture and agroforestry; (iii) retrofit buildings and industries with energy efficient appliances, replace energy inefficient light bulbs with very energy efficient LED lights (Light Emitting Diode), T5 lights (Tubular fluorescent lamps); (iv) promote afforestation/reforestation/restoration of forests, reduce forest fragmentation, reduce grazing in native grasslands; (v) promote low carbon power; (vi) reduce energy and water consumption; vi) recycle waste and use organic waste to produce energy or biofertilisers; (vii) implement zero waste, zero carbon emissions and zero carbon communities strategies; (viii) implement carbon capture and storage; (ix) implement carbon tax; (x) introduce a carbon footprint labelling system; (xi) promote low-carbon/green cities and provinces concept; (xii) implement low-carbon transport in cities (hybrid vehicles, electric vehicles, bus rapid transit, no-motorised transport); (xiii) implement tax rebates on green buildings; (xiv) invest in low-carbon technologies (Table 3), and RE; (xv) harvest rainwater and reuse and recycle waste water; and (xvi) provide incentives/subsidies on solar heaters, electric vehicles, energy efficient appliances.

Community Lifestyle and Behavioural Change Pathways to Achieve LCD

The community can play a significant role towards LCD. They (community) can walk or bike in urban

Table 3: Low-carbon technologies in transport and associated co-benefits

Improved diesel vehicles	• Promotes energy efficiency • Reduces local pollutants and GHG emission • Reduces use of non-renewable resources
Hybrid electric vehicles	• Promotes energy efficiency • Reduces local pollutants and GHG emission • Reduces use of non-renewable resources • Reduces noise pollution
Battery electric vehicles	• Reduces local pollutants and GHG emission • Reduces use of non-renewable resources • Reduces noise pollution
Solar electric vehicles	• Reduces local pollutants and GHG emission • Increases use of renewable • Reduces use of non-renewable resources
Alternative fuel-biofuels, CNG, LNG and LPG	• Reduces local pollutants and GHG emission
Non-motorized transport vehicles (walking, bicycles)	• Friendly to the environment and climate and energy efficient • Reduces local pollutants and GHG emission • Reduces use of non-renewable resources • Reduces noise pollution
Tyre pressure monitoring, adaptive cruise control/ collision mitigation, emergency brake assist/collision mitigation	• Promotes energy efficiency • Reduces local pollutants and GHG emission • Reduces use of non-renewable resources • Promote safety
Smart traffic infrastructure/intelligent transport systems/use of information technologies for traffic management	• Reduces local pollutants and GHG emission • Reduces use of non-renewable resources • Promote safety

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areas to attend works and shops (less than 3 km) (Figure 3a); use public transport (rather than using private cars) (Figure 3b); switch from bottled water to tap water (in developed countries, or where town water supply is safe to drink) (Figure 3c); switch key home appliances from standby to off when are not in use; reduce required home temperature by 2°C; retrofit homes with energy efficient appliances; support green jobs; support and promote LCD; install smart meters in homes; provide incentives for low-carbon lifestyles; provide funds for research and education on LCD; encourage investments in solar, wind, biogas; support local community energy initiatives; encourage less red meat and more plant-based diet (red meat such as beef has significantly higher carbon footprint) (Figure 3d); buy locally producing rather than imported goods and vegetables (imported goods have higher carbon foot in transportation) (Figure 3e), attend meetings/conferences via telephone or video conferences rather than flying there (WHO, 2008; Royal Geographic Society, 2016; Kibria et al., 2017b).

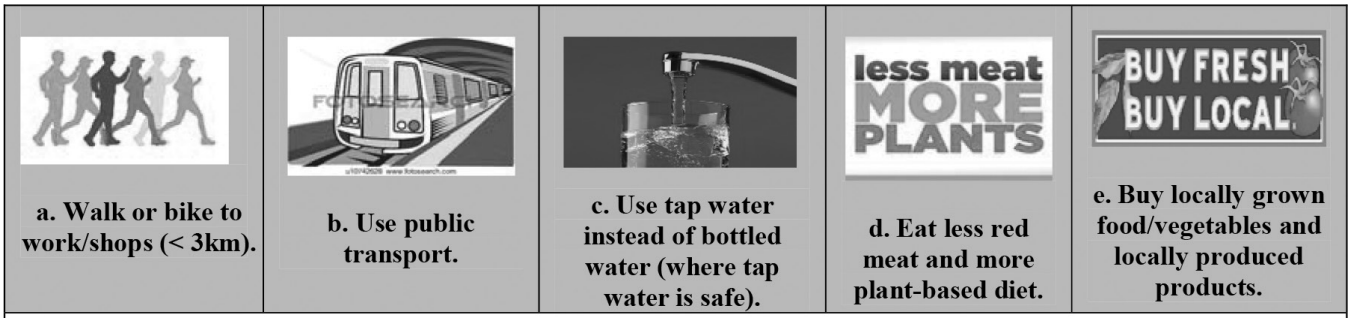

Figure 3: Examples of community lifestyle and behavioural change pathways for achieving LCD.
(Consult Table 1. Australia, Bangladesh, China and India have identified that awareness, education and behaviour changes of communities are an important strategy to achieve LCD)

Relationships between SDGs and LCD

On 25 September 2015, the 193 countries of the UN General Assembly adopted the 2030 Development Agenda, newly Sustainable Development Goals (SDGs) (which has 17 specific goals and 169 associated targets and more than 1000 indicators). SDGs are a new, universal set of goals, targets, and indicators that UN member states will be expected to use to frame their agendas and political policies over the next 15 years (2016-2030). We have identified that LCD discussed in this article (above sections) falls/aligned within the scope of the following SDGs for a sustainable future: SDG3, SDG7, SDG8, SDG9, SDG11, SDG12, SDG13, SDG14, SDG15, SDG17 (Figure 4). As this article is mainly aligned to LCD, therefore, it is beyond the scope to discuss further about SDGs in this paper.

Evaluation of LCD

The success of LCD can be evaluated via monitoring/ auditing and reporting of energy and resource consumption and GHG emissions on corporate assets including

(i) energy consumption (buildings and facilities, vehicle fleets streetlights),
(ii) water consumption (reticulated/piped and extracted),
(iii) office paper consumption (number of sheets/reams),
(iv) the number and types of energy efficient appliances installed in corporate assets (e.g. LED lights, T5 lights),
(v) green power purchased (low or nil GHG emitting solar PV, wind, hydropower),

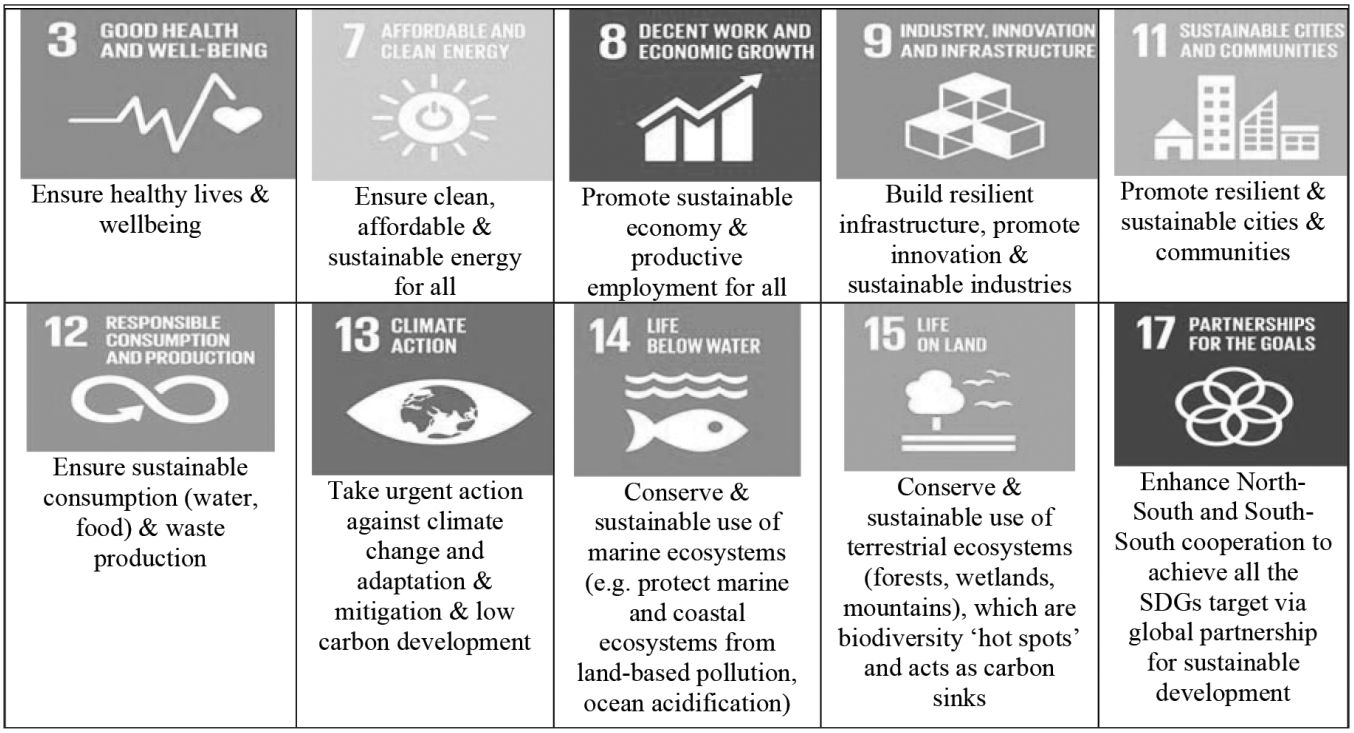

Figure 4: SDGs which are aligned to LCD and discussed in this article (readers are referred to Table 1).

(Consult Table 1. Australia, Bangladesh, China and India have identified several initiatives, policies, strategies, actions to achieve LCD that falls/aligned within the scope of the several SDGs. These initiatives, strategies etc. are targeted capping of green and renewable energy (SDG13); zero tillage (SDG13), climate-smart agriculture (SDG 13), climate smart fisheries & aquaculture (SDG14), agroforestry (SDG15); use of energy efficient appliances (SDG13), afforestation/reforestation/restoration of forests (SDG15); use of low carbon power (solar, wind, nuclear, hydro, biofuels) (SDG3); energy production from organic waste (SDG12); zero waste (SDG12), zero carbon emissions (SDG7,13); sustainable consumption (SDG12); carbon capture and storage (SDG13); carbon tax (SDG7,13); low-carbon/green cities (SDG11); low-carbon transport (SDG3,7); investment in low-carbon technologies (SDG8,9); rainwater harvesting (SDG12), R&D and innovation (SDG17) and subsidies on solar heaters, electric vehicles, energy efficient appliances (SDG8)

(vi) environmentally preferred products purchased (products that have a lesser or reduced effect on human health and the environment),

(vii) the number of staff travelled by air, the number of staff used public transport or private transport or walked or biked to travel to the office,

(viii) waste production (amount of wastes disposed to landfill, amount recycled and amount diverted from landfill) and

(ix) amount of GHG emissions and reductions against the baseline year comprising scopes #1, #2, #3 (for example, Scope #1 is the direct GHG emissions from fleet vehicles; Scope #2 is indirect GHG emissions from purchased electricity in buildings and facilities and Scope #3 is indirect GHG emissions from streetlights, water and paper consumption).

The number of staff members or local community trained up on the use of tools and technology related to LCD and adaptation to low-carbon lifestyle should be part of the evaluation. In addition, the revegetation, forests restoration and carbon offset programmes by plants should also be part of LCD evaluation (*Note:* Plants act as carbon sinks and carbon capture and storages; a tree can absorb as much as 48 pounds of carbon dioxide per year and can sequester 1 ton of carbon dioxide by the time it becomes 40 years old; trees while growing use sunlight to absorb carbon dioxide from the atmosphere through photosynthesis and store it as glucose (in the form of food), carbon (in the form of wood) and releases oxygen in the atmosphere).

Conclusion

LCD would help to avoid/reduce threats and risks posed by climate change to all countries in the world; it would create multiple economic, social and environmental benefits. There are several initiatives, strategies, policies and actions on LCD in Australia, Bangladesh, China and India. Those are awareness, education, capacity building and behaviour changes of communities on LCD; targets of capping green and renewable energy for short-, mid- and long-terms; zero tillage, climate smart agriculture, agroforestry; use of energy efficient appliances, afforestation/reforestation/restoration of forests; use of low carbon power (solar, wind, nuclear, hydro, biofuels); energy production from organic waste; zero waste, zero carbon emissions; sustainable consumption; carbon capture and storage; carbon tax; low-carbon/green cities; low-carbon transport; investment in low-carbon technologies; rainwater harvesting, R&D and innovation and subsidies on solar heaters, electric vehicles, energy efficient appliances. Some of the actions have cobenefits such as the revegetation and restoration of forests can play an important role in the protection of the coastal areas from the natural disasters (cyclones, tsunamis) in disaster-prone countries and minimise damage to life and property in addition to enhancing carbon sinks.

Investments in renewable energy (RE) technologies are essential for energy access, energy security, reduce dependency on fossil fuels, mitigating climate change and low-carbon economic growth and prosperity, in addition to creating new job opportunities in local areas. RE offers significant public health benefits to rural people in developing countries (where about 1.3 million people, mostly women and children, die prematurely every year because of exposure to indoor air pollution from the use of biomass as cooking and energy need) (Kibria, 2015). Courses should be introduced at schools, colleges and universities so that people can understand and be equipped with tools and technology related to LCD.

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