Climate Change **Mitigation** & **Adaptation** strategy for **Leh Town**

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MCL
Municipal committee of Leh

LIVEABLE LEH

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LEDeG (Ladakh Ecological Development Group) works on promoting ecological and sustainable development that harmonises with and builds upon local traditions and culture of Ladakh .

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Liveable Leh Project - The overall objective of the project is to strengthen capacities of the local government, the Ladakh Autonomous Hill Development Council (LAHDC) to make Leh, its prominent capital city and surrounding areas more environment friendly and a symbol of resilient and sustainable urban development.

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Author : Konchok Tashi (Urban planner)
Co-Author : Dachen Lamo (urban planner)
Lakshya Sharma (Architect)

Design By : Skalzang Otsal (Graphic Designer)

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Table of Contents

Introduction

Urban areas are growing at an unprecedented rate, cities with its economic growth, human development and increasingly rapid urbanization creates multiple issues, it faces many interconnected environmental, social and demographic challenges. As more than half of the world population living in the cities, the urban areas are one of the major contributors of climate change, refers to a change in the Earth's energy balance, leading to either a warming or cooling effect over time. Climate change results in increased in frequency and intensity of natural hazards and it presents a catastrophic risk to the cities.

The Liveable Leh project aims to create a climate resilient Leh, that works towards solving urban issues and gearing towards combating climate change. Cities have the potential to be the main implementers of climate change resiliency and adaptation. In 2015, the UN adopted agenda 2030 for sustainable development, and with the goal number 11 it aims to make cities and human settlements inclusive, resilient. Safe and sustainable. As cities lies at the core of the sustainable development agenda, cities around the world are gearing towards combating climate change and the local urban government plays an important role in tackling climate change.

Urban areas need weighty changes and rational and systematic shift in transportation, energy, land use, ecosystem, water use, growth pattern, consumption and lifestyle. It needs to start developing and implementing climate change actions, getting started now will help avoid heavy investment in the urban systems.

Leh Town

Leh town is one of the two urban centres in Ladakh and administrative headquarter of Union Territory of Ladakh. A Class 3 town, which comprises of 13 municipal wards with a total population of 30,870, (as per Census 2011). The town is situated at an elevation of 3500 m (34o 17'N and 77o58' E).The municipal area measures 17.6 sq.km. It is an important tourism town and the educational, political and the economic centre.

It has been experiencing rapid growth in its population since the 1990s. It also supports a floating population that comprises of labourers, defence personnel and tourists. The town is the most urbanised area in the Ladakh region, it attracts lots of migrants from all over the region for job opportunity.

Leh is unique in terms of terrain, climate, ecology and geopolitics. It is a cold mountain desert with a fragile ecology that can support only a certain amount and type of development and activity. The terrain is spectacular, but challenging, especially in winter.

The town is situated between the Karakoram range and the greater Himalayas and Zanskar ranges which causes a rain shadow effect resulting in extremely Low annual precipitation, the town and its nearby villages are dependent on the magnitude and nature of precipitation for agriculture, greenery, lifestyle and water resources. The town also relies on the Northern Glacier (Khardungla) for the surface water.

Climate change in urban areas

Urban areas contribute to a major share of greenhouse emissions of a region, and significantly contributing to climate change and its impact. Energy intensive activities such as manufacturing, transportation, commercial activities, and other intensive economic activities are contributing to greenhouse gases more than any other activities. Moreover, lifestyle in urban areas is more energy intensive and thus more carbon intensive. Domestic water consumption in urban areas is more than those of rural areas. Per capita electricity consumption in urban areas is more than rural areas. And thus, carbon footprint of an urban household is more than a household of a rural area. All the infrastructures are concretized in urban areas, even the water canals are concretized. Concretization of infrastructures has led to the depletion in ground water recharge and more surface runoff.

Urbanization is also associated with a situation called urban heat island. Urban areas and cities are certain degree warmer than the surrounding areas, due to the presence of heat absorbing materials such as concrete buildings and pavements, and due to the lack of vegetation, which creates evaporative cooling effect. Within a city itself, various neighborhoods experience different microclimatic conditions.

Urban governments/ urban local bodies can play critical roles in adaptation to climate change as well as mitigation of climate change impacts. Low- and middle-income countries have three-quarters of the world's urban population. Also, these countries have most of their urban population at greater risk from the climate change impacts. Most of the nations would face the challenge of fresh water availability in the coming years. China, India and Africa would face the problem of sea level rise as these countries have more than a quarter of the world's population within low elevation coastal zones.

However, most of the times local governments in these countries don't have capacity to mitigate all the climate change hazards. For many climate changes hazards, local governments can reduce impact of the hazard, for e.g., through construction of better-quality infrastructure, traffic management, efficient waste management, etc. Thus, action on climate change adaptation and mitigation by the local governments/ urban local bodies is very crucial.

Climate change in Leh town

Human civilizations have thrived high altitudes, as evident in Tibet, Bolivia, Ecuador and Nepal, and all these regions have developed intricate cultural systems to conserve their environment while also harnessing its (sometimes scarce) resources. Ladakh is no exception.

Most of these regions are facing the challenge of social, economic and climatic change. High altitudes are the first to be impacted by climate change, which directly impacts the delicate environmental systems such as glaciers, snowfall, and weather patterns which in turn can lead to floods, agricultural disruption, landslides, water shortages and so on.

Leh town being the urban center of the region attracts a huge floating and migrant population, resulting in extensive load on natural resources and physical infrastructure.

The town and the surrounding villages were completely dependent on natural resources and agriculture for the basic needs, and had a complex and intricate system of water supply through natural springs, canals and ponds, supplying water from the upper glaciers, bogs and springs.

The town had an ample of green spaces and marshes at areas with high water level, with the arrival of tourist after 1970s and 1980s the economy of the town shifted to tourists, agricultural lands have been converted for constructing hotels and guest houses, worsened by low annual precipitation specifically in winter months,

The Khardungla glacier, the predominant source of water for agriculture received low snowfall to sustain the supply of year-around water to the town, over extraction of ground water by residents, hotels, government departments and army reduces the marshes to barren lands.

The town is highly dependent on outside larger cities even for basic necessities, the lifestyle of the residents evolved to consumer society. New sub-urban areas emerged around the town, the houses in Leh town are energy intensive, built with unsuitable construction materials, it imitates modern design with heavy water usage to maintain the toilets and bathrooms.

The houses are poorly insulated which needs firewood heaters, producing 9.5 kg of carbon emission per night per household, the Town produces almost 73 tons of Carbon per night for 5 months. Thus, carbon footprint of a household has increased significantly.

Carbon emission from the space heating system is one of the major reasons of air pollution and hence major contributor of climate change, followed by improper and inefficient urban management.

The town lacks efficient infrastructure, and is still struggling to provide an efficient public transport, pedestrian infrastructure, water supply, waste management etc. Leh has become a car-oriented town with congestion and parking problems with just 13.5 percent of the municipal area under public transport coverage. The town doesn't have any facilities for non-motorised transport and scored just 44.6 in the global walkability index.

Lack of proper, suitable and partial implementation of building byelaws, has encouraged carbon intensive houses with no open spaces, resulting in imbalanced urban ecology and improper management of solid and liquid wastes, further creating a source of pollution and greenhouse emissions.

Quality of life, security and economy are intricately woven with the climate of the region the environment has been largely neglected in the course of Leh's growth—which has not only reduced the natural resources such as clean water and safe land available, but has increased vulnerability to natural disasters.

The massive flood in August 2010 which killed over 255 people, damaged agricultural lands, property, infrastructure and various services, showed the impact of poor urban planning and lack of early warning and crisis management systems—and no action has been taken since to address these issues, leaving the town as vulnerable as before Leh must still focus on making its residents more environmentally conscious, revitalise traditional systems and find new solutions to manage and protect natural resources, and increase resilience against future disasters.

Such actions will not only collectively help Leh to adapt to the impacts of climate change, but will increase the happiness people feel when living in true harmony with nature.

- **Major causes**
    - Space heating and energy intensive buildings
    - Car oriented mobility system
    - Improper solid waste management
    - Over extraction of ground water
    - Mismanaged urbanization
    - Land use – loss of natural springs
- **Effects**
    - Landuse change
    - Degrading surface water system
    - Air pollution in winters
    - Flash floods
    - Uncertain rainfall and Snowfall
    - Misbalanced urban biodiversity
- **Opportunities and potential**
    - Water, energy and food security are closely linked.
    - Availability of Renewable energy for space heating, insulation of building
    - Potential for green modes of mobility.
    - Waste management can be made efficient.
    - A carbon neutral town.

Climate observation

The town is situated between the Karakoram range and the greater Himalayas and Zanskar ranges which causes a rain shadow effect resulting in extremely Low annual precipitation, the town and its nearby villages are dependent on the magnitude and nature of precipitation for agriculture, greenery, lifestyle and water resources. (Chevuturi, 2016) in their article on 'climate change over Leh' analyzed statistically the current and changing trend of climate change over Leh, using climate dataset from different sources and they found out that climate over Leh town shows a reduced precipitation trend and a warming trend in the last decade.

The annual mean temperature of the town is 7.3o C with average daily precipitation rangers between 0.5 – 1.5 mm/day, it defines Leh town's climate as cold and dry (Chevuturi, 2016).

(Chevuturi, 2016) used different datasets and analyzed using polynomial trend lines with comparative analysis between different datasets, and observed a warm period from 1901 to 1979, lowering temperature and colder period between 1979 to 1991, the temperature increased rapidly after 1991 onwards.

There was a low precipitation period before 1970, and between 1970 and 1995 there was increasing trend of precipitation, after 1995 the precipitation trend starts to decrease, with high precipitation rate in 2010 and 2012. Their research shows an inverse relationship between temperature and precipitation, as before 1970s there was a relatively warm temperature with low precipitation rate, and after 1970s till mid 1990s the region receives higher precipitation with Lower temperature. And after 1995 the temperature stated to increase with precipitation rate decreasing.

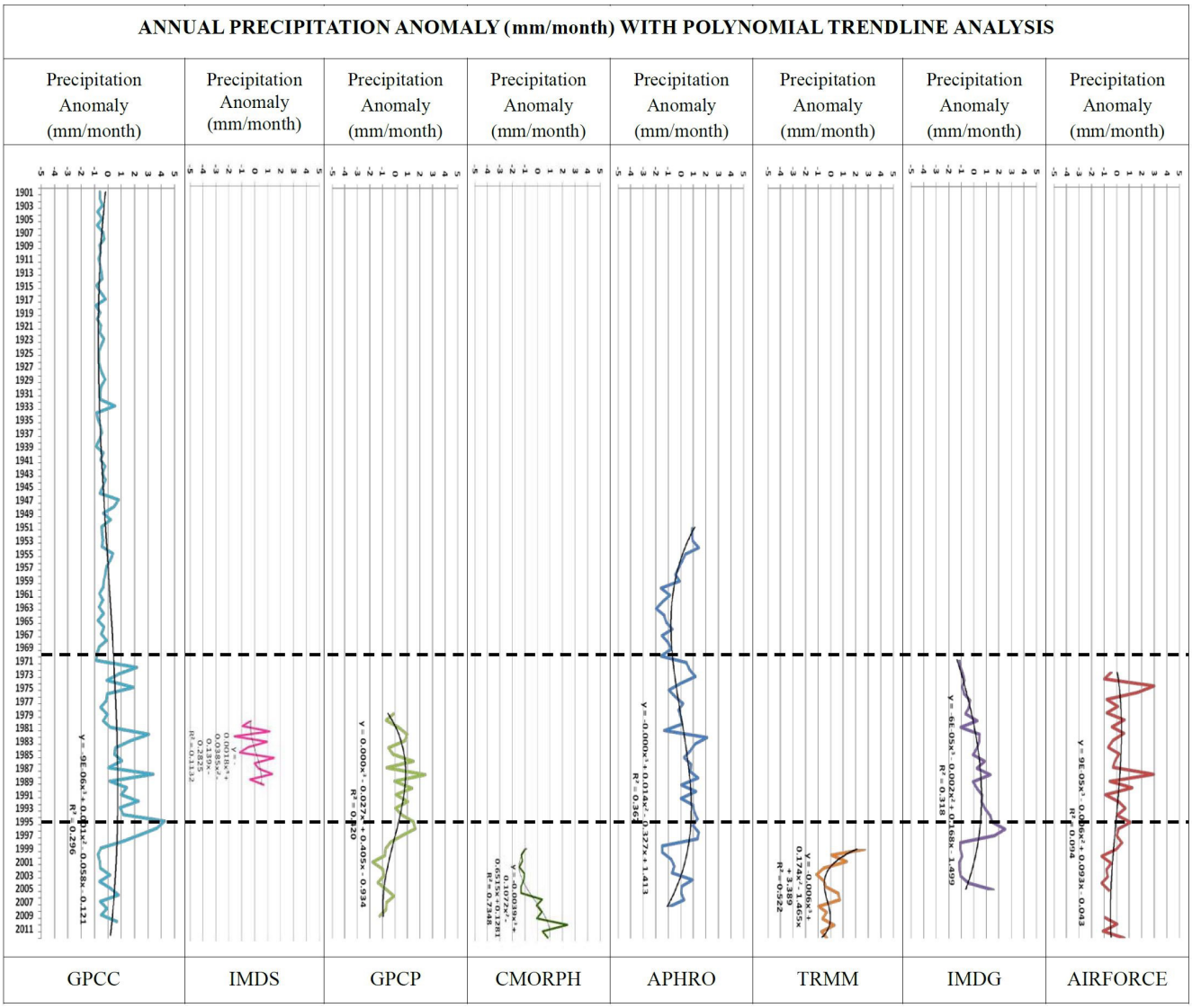

Figure 1 Annual Precipitation anomaly with polynomial trend line analysis (black line) over Leh for different dataset sources (Chevuturi, 2016).

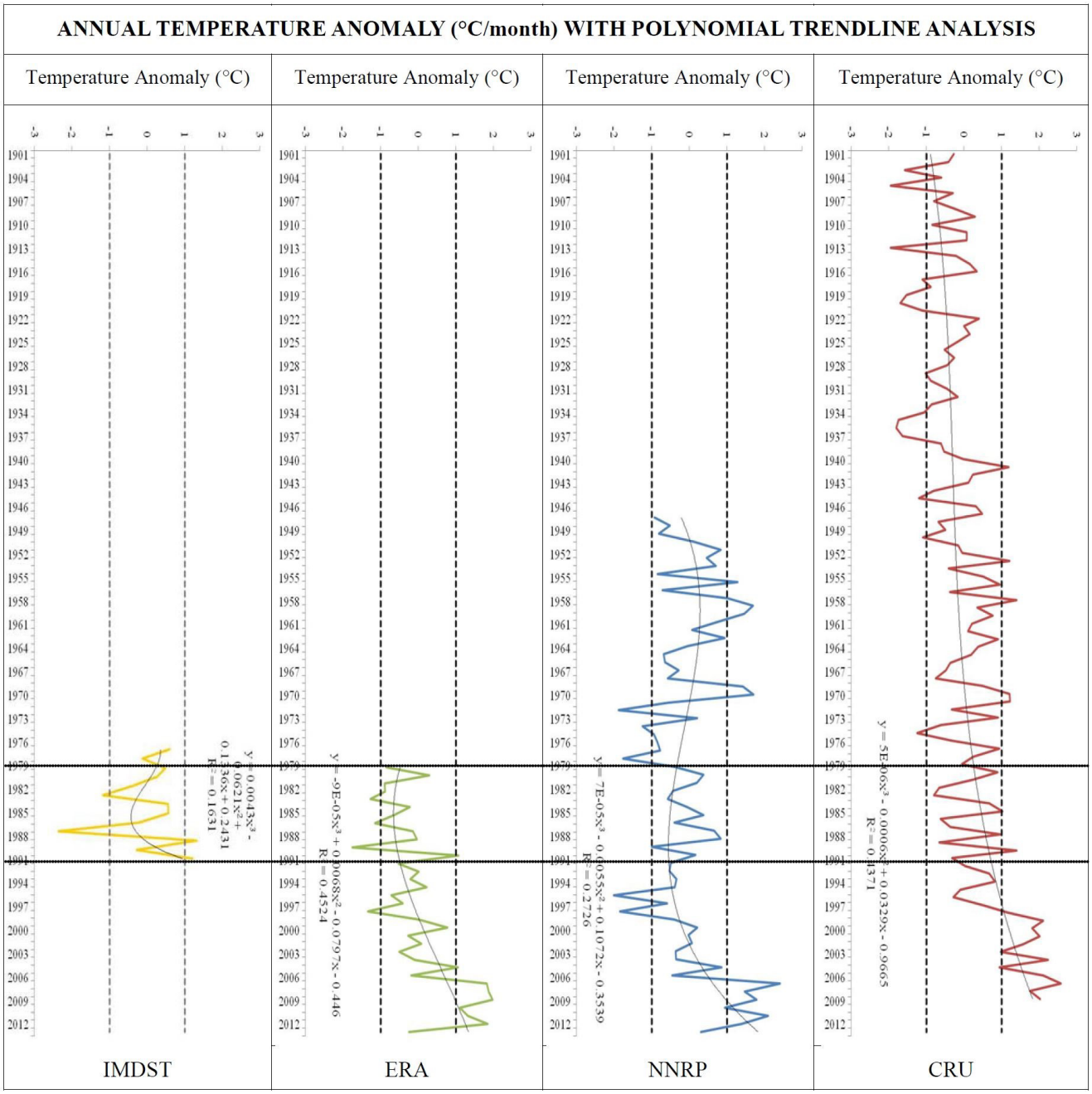

Figure 2 Annual temperature anomaly with their respective polynomial trend line analysis (Chevuturi, 2016)

The study indicates the varied precipitation patterns and rise in temperature in Last decades foreshadows a changing climate and higher chances of unexpected event over Leh in coming years which may result in devastating consequences such as flash floods, cloud bursts and droughts.

Leh region and its ecology is adapted to its climatic consistency from many years, a slight change in its climatic consistency will disrupt the delicate balance of the ecology of the region, with significant impact on vegetation, settlements, wildlife, hydrology, glaciers, agriculture and lifestyle of the society.

Therefore, Leh town and the region needs a strong climate change adaptation policies.

India's Intended Nationally Determined Contributions – Towards Climate Justice

The Paris Agreement was adopted by 196 Parties at COP 21 in Paris, on 12 December 2015 and entered into force on 4 November 2016. By 2020, countries submit their plans for climate action known as nationally determined contributions (NDCs). In their NDCs, countries communicate actions they will take to reduce their Greenhouse Gas emissions in order to reach the goals of the Paris Agreement. India also submitted its NDC, and it is considered one of the most ambitious NDC. Following are the pledge taken by India in the NDC:

1. To reduce emission intensity of GDP by 33-35% till 2030 from 2005 level.

2. To achieve 40% of electric power installed capacity from non-fossil fuel by 2030.

3. To Create additional carbon sink of 2.5 -3 billion tons of CO2 equivalent through additional forest and tree cover (increase of about 680 - 817 million tonne of carbon stock).

4. To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.

5. To Mobilize Domestic and New & additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.

6. To build capacities, create domestic framework and international architecture for quick diffusion of cutting-edge climate technology in India and for joint collaborative R&D for such future technologies.

7. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.

8. To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.

Ladakh carbon neutral strategy

Ladakh Union Territory administration has launched Ladakh carbon neutral strategy plan. The Ladakh carbon neutral strategy has focused into five main sectors, energy; transport; agriculture and forest; urban management; and tourism. The strategic document discusses about the issues in these sectors which leads to climate change and have suggestions and recommendations to adapt to climate change impacts. Following are some of the issues discussed in the document:

1. Grid extension challenges: Due to rough terrain of the region grid extension from the Alchi hydro-power plant is a great challenge, which has led to the higher dependency on the diesel gen-sets in the other parts of the region and thus, higher GHG emissions.

2. The massive contribution of the transport sector to the overall GHG emissions owing to the growing tourism, high private vehicle movement, inefficient public transport system and army fleet movement.

3. Delayed snowmelt and winters with less snow lead to minimal water availability.

4. The installation of private bore wells has increased multi fold in the last few years in Leh and there is no proper permit or fee structure in place to monitor.

5. Unplanned urbanization

6. Fading traditional practices, such as usage of locally available materials, usage of dechods (traditional toilets), dZing (ponds), Churpon (traditional water management system) etc.

7. Tourist sector in Leh town generates about 5.11 metric tonnes of waste/day during the peak tourist season from April to September, with a per capita waste generation of 1.87 kgs/day/room.

Recommendations and strategies given in the document:

1. Renewable energy actions at domestic level through policy interventions, such household usage of solar water heater, solar cooker, solar passive houses, radiative solar air heater etc.

2. Construction of solar passive house and usage of locally available and suitable materials for construction.

3. Incentivising non-motorised and electric transport- Ladakh has several tour operators who offer two wheelers and three wheelers for hire/rent. Such operators should be encouraged to provide bi-cycles and e-bicycles for travelling in around Leh.

4. Encouraging homestays and guesthouses that follow traditional practices such as dry toilets, promote local cuisine and provide eco-friendly services including no use of plastics and utilise solar for energy and water heating to the maximum extent possible.

VISION

The climate change strategy aims to create a climate resilient Town with actions to reduce greenhouse emissions and sustainable management of key carbon emitting sectors such as Traffic and transportation; energy; solid waste management; surface and ground water; and urban ecosystem.

Policy objectives

1. **Traffic and transportation**
   Develop a comprehensive and eco-friendly urban mobility plan, that focuses on sustainable public transport system supported by a pedestrian and cycle friendly environment

2. **Energy**
   Introduce and implement Low carbon space heating technologies and prioritize efficient homes and mandatory room insulation in the building codes.

3. **Solid waste management**
   Adopt 4Rs: Reuse, reduce, recycle and recovery and aim to provide 100% Door-to-door collection of 100% segregated waste while reducing the waste which goes to final dumping site by 20 percent by 2030

4. **Surface and ground water**
   Manage all water resources to use responsibility and protected from pollution, reducing dependency on ground water while ensuring food and water security for future generation.

5. **Urban ecosystem**
   Conserve and expand the natural water system of wetlands, water bodies and channels throughout the town, while using it for recreational and urban design elements in sustainable way while increasing the green cover in the town through parks and bogs

6. **Disaster Resilient town**
   Prepare a robust and advanced disaster detection and early warning system for floods, earthquakes and other natural disaster, with effective disaster response plans and agencies

Sector-wise interventions

Climate change mitigation and adaptation strategies for Leh town, focuses on key carbon emitting sectors: **Traffic and transportation; energy; solid waste management; surface and ground water; and urban ecosystem.**

1.1. Traffic and transportation

Assessment

Transport is an essential part of modern life, but it comes with a high cost in increased greenhouse gas emissions and air pollution. Leh being a part of a sensitive Himalayan region, have to work on meeting the mobility needs, more sustainably and effectively.
Leh is a monocentric town and faces different transport related challenges. This includes traffic congestion as most trips converge towards city Centre, inefficient public transport as only 13.5 percent of the municipal area is under public transport coverage, with 86.5 percent of total municipal is transit desert and lacks transit facilities i.e. no public transport access, inconvenient walking infrastructure, no cycling infrastructure, people using car even for short trips. These reasons lead more traffic congestion in the city Centre and other commercial areas thereby increasing parking demand (Tashi, 2021).
Leh town is the district headquarter and nearly all registered vehicles end up in the town. Leh district has seen a drastic change in its economy and population since 2010. Though, tourism has brought prosperity to the region, the influx of people from outside has also increased. Additionally, the increase in population is also reflected in the number of cars on the road.
The dependency on cars has increased as evident from the number of new cars registered at the RTO office. The number of cars registered in 2010 was 218, which increased gradually till 2017 (967) and then shot up to 1,439 in 2018. The overall count of private cars is 9,014 till 2019. Similarly, the number of two-wheelers in the region too has increased gradually.

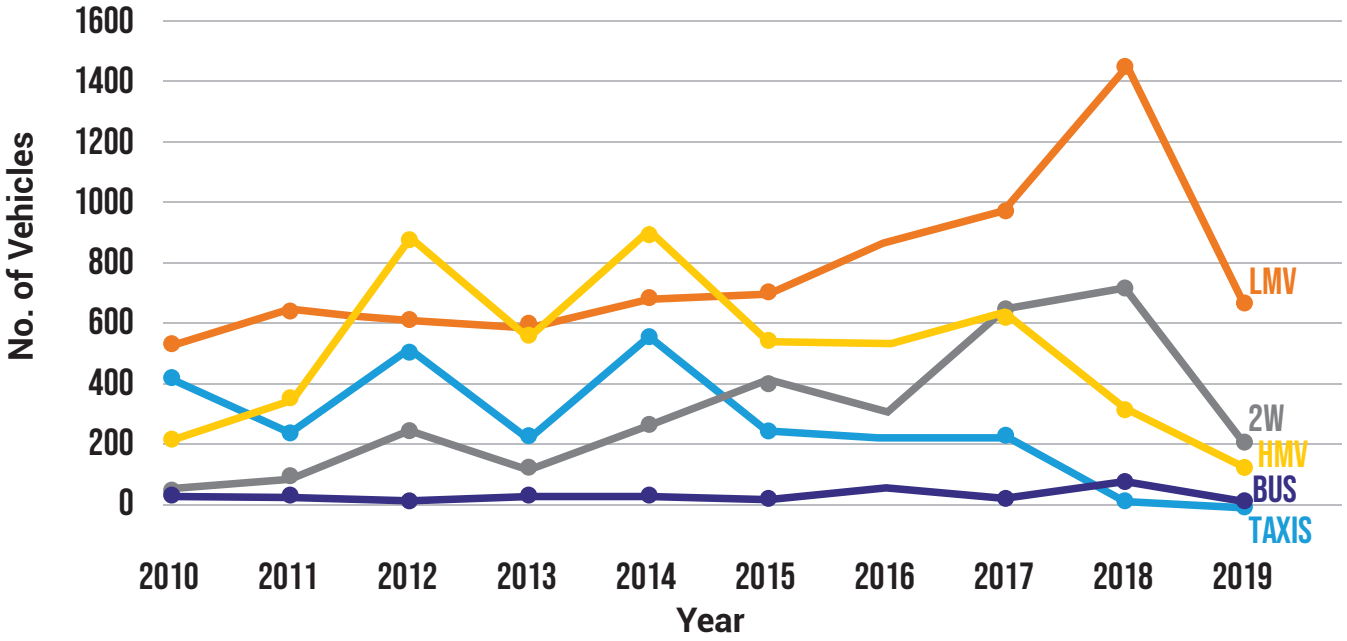

Figure 3 Yearly vehicle registration in Leh district

The figure shows vehicle registrations at RTO Leh. In addition, it is estimated that about 10,000 cars registered outside Leh (Kargil, Srinagar, Jammu, Delhi and Chandigarh) operate extensively in the Town. There are 4,454 registered taxis in the RTO as of 2019 but at least 5,000 taxis bring tourists to Leh from outside regions and stay in Leh for the tourist season from May to October. 16 buses were registered in 2010 and 62 in 2018.

Due to its urban sprawl, land-use and satellite towns that have emerged around Leh's municipal boundary, the town attracts a lot of traffic and travelers who are directly dependent on the city Centre for business, office, shopping and educational purposes.

Emissions from transport sector

The annual utilization of single car in Leh is 12,000 km and a taxi and rental bike whose trips originates form Leh town on average is 32,000km and 29,000km respectively, the annual utilization of all the public transport buses in Leh town including Choglamsar is 4,28,875 kms.

So, the annual total emissions in transport sector in Leh town is 64,852.715 metric ton Co2.

Type of vehicle	Km driven per year	Total no of vehicles	Carbon emitted per Km	Total emissions
2 wheelers	29000 km/Vehicle	3324	0.0595 kgCo2/km	77,13,342 kgCo2
Cars	12000 /vehicle	11431 +10,000 (unregistered)	0.140 kgCo2/km	3,60,04,080 kgCo2
Taxis	32000 /vehicle	4053	0.161 KgCo2/km	2,08,81,056 kgCo2
Bus (public transport)	4,28,875	(Trips per day is considered)	0.5928 kgCo2/km	2,54,237 kgCo2
Total				**6,48,52,715 kgCo2 64,852.715 metric ton Co2**

In Leh town there is an urgent need to reduce the use of motorized transport by developing environmentally-friendly and sustainable mobility solutions that provides a healthier and liveable environment for its residents.

Leh town needs an effective and long-term solution for sustainable urban mobility by creating ideal conditions for the use and promotion of alternative environmentally-friendly modes of transport such as walking, cycling and efficient public transportation.

The way forward will require a change in philosophy. Instead of planning for traffic and moving cars as efficiently and quickly as possible, we need to concentrate on moving people as efficiently and quickly as possible.

Policy

Develop a comprehensive and eco-friendly urban mobility plan, that focuses on sustainable public transport system supported by a pedestrian and cycle friendly environment.

1. **Make it easier to live without cars - Make Leh town walkable and bikeable.**

   The streets in Leh should be upgraded to make it more convenient and safer for people to walk and bike, and upgrade market places along roads, partial pedestrianized as much as possible.

Strategies

- Develop a complete street policy for Leh town – that focuses on making streets cycling, walking, riding public transit and driving safe, comfortable, reliable and affordable. With better lighting, crossings, and street furniture's.
- Promote cyclability in Leh city center through public cycle sharing system with pen route system.
- Promote and incentivize buying and using of electric cycles.
- Aim for a modal shift to atleast 1/3 of all driven traffic trips being by public transport and 1/3 by NMT including walking.
- Improve the public transport and pedestrian infrastructure in such a way that it takes no more than 20 minutes to get from home to any part of the town & 10 minutes by walk from home to nearest urban centre. (for more information, refer Walkable Leh – a sustainable public transport for Leh Town).

2. **Encourage electric vehicles – Leh towards a sustainable future**

   Leh should be ready for the future of mobility i.e., electric vehicles. focusing on accelerating the pace of electric vehicle adoption, specifically in the segments of Public transport, two-wheeler and private cars, and electric cycles.

Strategies

- Reserve space and land for charging station, EV oriented bus stops, bus depots, service centers and dealerships etc.
- Financial incentives -Tax incentives on the loans taken for purchasing electric vehicles
- Waiver of Road taxes and registration fee of electric vehicles.
- Constitute a urban electric vehicle board comprising of members from regional transport authority, municipal committee Leh, Leh development authority, LAHDC and UT Ladakh administration; committee will look after the introducing new technologies in the town, creating awareness about electric vehicles, functioning of electric public transport system and creating and updating Leh EV policy.
- Provide skill development program, set

up training centers for jobs and skills needed in EV sector.

- Introduce electric cycle sharing system in Leh town.

3. Sustainable public transport for Leh town

To lower the emissions and over dependency on private cars, Leh should drastically improve its public transport system to cover more than 80 percent of the town with smart, affordable, integrated and electric public transport system.

Strategies

- Introduce new bus routes such as: Leh gate to Gangles; Leh gate to Murtse and Dambuchan; Leh gate to Choglamsar via Choglamsar village; solar colony and Mahabodhi road; Leh gate to Skara yokma via Skalzangling; Ring route – Sankar- Yurtung- upper Changspa –Gh –Skara; Leh gate to Skampari.

- Introduce Low emission buses or electric buses and reserve space for charging stations, bus depots and bus stops.

- The buses should be universally accessible, low floor with reserved space and seats for physically challenged and wheel chairs.

- Integration of public transport with different land uses such as schools, employment centres, residential and commercial areas to make whole Leh town accessible through public transport

- Develop a New transit exchange at old bus stand - Bus drop and pickup point at Leh gate causes traffic and accidents, to solve this issue new transit exchange at old bus stand should be developed

- Introduce intelligent transport system in its public transport and even cycle sharing. ITS systems will drastically improve the operation, maintenance and sustainability of the public transport system.

- Integrate public transport system with cycles through bike-on-board facilities and regulations, bicycle parking facilities at stations, cycle rentals at transit interchanges etc.

1.2. Energy

Assessment

The energy sector will play a critical role in making a Leh energy resilient town. Initially the energy generation and distribution in whole Ladakh was fossil fuel based. The energy demand of the town largely differs as per weather conditions and seasonal variations.

There is total 6857 households in Leh in the year 2018. As per Indian standard demand of electricity is 32.5 unit per month/ consumer in urban areas for residential uses. This implies that electricity demand of Leh town is 2,22,852 unit of energy per month only for residential uses.

Currently 100 % of the energy demand of Leh during summer is fulfilled by the Alchi hydel power plant., while during winters energy demand rises due to use of electric-based space heating system in energy inefficient houses. Alchi project generates about 45 megawatts of power. Ladakh during summer require only 15 megawatts of electricity whereas remaining 30 megawatts is supplied outside Leh (Kargil and J&K). But during winter Leh requires more than 15 megawatts, which Alchi project cannot generate during winter, and is supplied from outside. Total energy consumption in Leh town is 19.9 kwh per capita, it increases in winter months due to heating needs.

The most common technology used for space heating in Leh is a metal furnace called "Bukhari", which has a chamber where wood/dry cow dung is inserted and burnt using kerosene oil. Kerosene run heaters are also used mostly be the government departments and army.

Under the public distribution system, 120 litres of kerosene is supplied per year to households in Leh, for domestic use. This is recorded data from PDS, the amount used in Leh town is likely much higher than this. On average 2 litres per night kerosene is used to run kerosene based heaters in households in Leh. Burning 1 litre of kerosene leads to release of 2.5 kg of carbon dioxide into the atmosphere.

The houses are also poorly insulated which needs firewood heaters, producing 9.5 kg of carbon emission per night per household, the Town produces almost 73 tons of Carbon per night for 5 months that adds up to 365 tones in a year. Moreover, dilapidated bukharis may cause indoor pollution as well, through chimney leakages . Thus, carbon footprint of a household has increased significantly.

Other ways in which residents of Leh heat their homes is using electric heaters, these heaters directly do not contribute a lot to carbon emissions but run-on electricity. Though, much more expensive than the metal furnace or "bukhari", the use of these heaters is a better alternative as there is no direct carbon emission. There are measures that can be implemented to increase the insulating properties of homes which in turn can lead to better retention of heat generated by the heaters, thus the electrical heaters will run for lesser hours thus reducing use of electricity.

Carbon emission from the space heating system is one of the major reasons of air pollution and hence major contributor of climate change.

Technology Soluiton	S.no	Technology	Fuel Type	Cost of Technology (in INR)	Energy fuel consumption (kg/h) or (L/h)	Total emissions (kg co_2/h)	Strenght	Limitation
Existing space heating technologies (rural areas)	1	Saggar	Wood	1,000-3,000	2-3	4-5[8]	• Container provides easy mobility. • Cost of the product is low.	• Used in small habitats only. • Leads to indoor air pollution.
	2	Bukhari	Wood	2,000-8,000	3-4	6-4[9]	• Less expensive in areas where wood is abundantly & freely available. • Can be deployed for cooking as well as in space heating.	• Leads to both outdoor & indoor air pollution.
	3	Army kerosene heater*	Kerosene	3,000-20,000	0.64	1.6	• Less expensive to use in contrast with other space warming innovation technique, for eg. Bukhari, Saggar. • Provide instant heat, thereby eliminating the waiting time to warm up. • Capable to heat larger rooms.	• Not recommended for use in airtight spaces as this leads to poor indoor air quality. • Sleeping with a keresene heater 'on' is not recommended.

As per a study of emissions by WWF India, 3 per cent of the emissions from space heating comes from commercial buildings. For the remainder, about 19 per cent is recorded from residential buildings in urban areas and 78 per cent from residential buildings in rural areas. The projected scenarios in this study suggest that there is a likelihood of an increase in the share of emissions from 17.8MT CO2 in 2030 to 18.9MT CO2 in 2040 (wwf india).

Thus, Himalayan areas that experience harsh winters need to adapt to ways of space heating that do not contribute to greenhouse gas emissions or do so sparingly

Challenges in execution of low carbon space heating

Strategies

The following challenges may arise when it comes to implementing carbon neutral measures for space heating:

1. High upfront costs of making better insulated buildings and implementing carbon neural space heating technologies, may deter people from investing in these technologies.

2. Bringing in changes to an established systems and consumer behaviors is difficult as people have trouble adapting to new technologies.

3. Lack of financing options for entrepreneurs that would want to commercialize low carbon pace heating technologies.

4. The operation and maintenance of prevalent methods is easier and the skills required for those are taught in households.

5. Lack of institutional frameworks to strengthen implementation.

Policy

Introduce and implement Low carbon space heating technologies and prioritize efficient homes and mandatory room insulation in the building codes.

Strategies

1. **Converting heating of individual buildings to renewable technologies**

   Several technologies can be implemented in order to achieve comfortable room temperatures, while using less fossil fuel intensive methods,

   - **Incentivize the use of solar energy using pebble bed solar heating technique.**

     This technology draws heat from the sun. Solar collectors, placed on the roof collect heat and through a solar tower, i.e., a duct the hot air is carried down to an underground bed of pebbles, under the ground floor. The pebbles store heat and emit it through the floor, acting as a measure for floor heating.

   - **Research and develop the use of Geo thermal heat pump system for space heating.**

     This technology draws heat from under the ground surface as temperature under 4 to 10 feet of the ground is constant around 54 degrees Celsius, this constant temperature is use to achieving comfortable room temperatures, by

installing pipes 4 to 10 feet under the ground and connecting them to a heat exchange pump in one of the rooms in the building we wish to heat. The pump draws cold air and sends it down into the underground pipes where the air gets heated and sent back up and is expelled into the house by the pump. The warm air can also be circulated around the building using ducts.

- Introduce and incentivize the use of Solar heating using photo voltaic solar panels

  This technology draws heat from the sun. Photo-voltaic solar panels that convert heat from the sun into electricity can be installed on roof tops which will generate electricity to run conventional electric heaters. It can be re retrofitted into an existing house, Less hassle, requires less adaptation. But it is cost intensive compared to other techniques and requires expertise for installation and maintenance.

- Adopt and popularize solar wall and Trombe wall design techniques

  A solar wall is a wall, painted black and has glass frame attached to it, with 3 to 4 inches of space between the glass and the wall. The black wall absorbs heat from the sun and the glass stops it from escaping outside. This way the heat is released on the inside and the temperature inside is warm

  Trombe wall is painted black after 9 inches of gap with a glass frame right outside it. The principle is the same as that of the solar wall where the black painted wall absorbs the heat, which is trapped by the glass wall. Small exchange gaps in the black wall, one at the bottom, another at the top will work to circulate the heat trapped between the black wall and glass wall inside the room.

2. **Building efficiency and reducing energy demand:**

   - Insulation

     Through proper insulation the heat inside the house can stay for longer, increasing the efficiency of the heating technology implemented in the building.
     Insulation materials ranging from saw dust (organic) to thermocol and glass wool (industrial) can help achieve this efficiency. A 4 to 6 inch thick layer of these materials inside the walls of the house can be filled during construction. For buildings already built the insulation can be retrofitted by building a wooden frame, adding an extra layer with space between existing wall and outer most layer which can be filled with desired insulation material.

3. **Introduce initiatives to boost entrepreneurial activities amongst new entrepreneurs to start commercializing alternative heating technologies, which will lead to mass production and reduce costs in the long run.**

4. **Introduce subsidies for owners who are building their house using earth, insulation materials and implementing alternative heating techniques.**

5. **Outlaw traditional, carbon intensive heating technologies such as Bukhari.**

6. **Start recycling drives by collecting discarded bukharis for an intensive to promote use of alternative heating techniques**

1.3. Solid waste management

Assessment

Municipal solid waste management is inseparably linked to development, increasing urbanism and climate change. The ability of the town municipal authority to manage and improve the Solid waste management provides large opportunities to mitigate climate change and generate co-benefits like health and environment conservation.

Almost three to four percent of global greenhouse gas emissions comes from improper waste management, produced mainly in landfills. So, Landfill gas-to-energy is an economical technique for reducing greenhouse gas emissions from the solid sector.

The Municipal Solid Waste generated in Leh town is estimated to be 38.8 tonnes in the summer tourist months and 9.2 tonnes in the winter months. The average per capita waste generated in Leh town is 0.47 kg (Angmo, Dorjay, Spalzes, & Paljor, 2021). On an average, tourist accommodation of Leh town generates about 5.11 tonnes of waste/day during the peak tourist season from April to September, with a per capita waste generation of 1.87 kgs/day/room.

Municipality has deployed tippers to collect waste from door to door wherever possible. Different locations have different frequency of waste collection. An effort is being made to collect segregated waste form these households. The four tipper vehicles have a single compartment to carry different categories of waste while the three smaller vehicles have different compartments for dry and wet waste (Angmo, Dorjay, Spalzes, & Paljor, 2021).

In terms of waste collection, door to door garbage is picked up from households and commercial establishments and no effort is made to segregate the waste at source for recovery and recycling purposes. Primary evidence suggests that uncontrolled dumping and burning at the Bombgarh i.e., the landfill site, which is located in a residential area and thereby residents are exposed to various health hazards. There is no effort undertaken to recover necessary materials (metals, glass, ceramics, plastics) from various types of waste such as construction and demolition, municipal solid waste, due to lack of relevant infrastructure which severely undermines the potential to develop Leh into an energy resilient town.

Reducing greenhouse gas emissions in the solid waste sector can improve public health; improve quality of life; and reduce local pollution in the air, water, and land while providing livelihood opportunities to the urban poor. Leh should set goals for emission reduction by using existing

technologies to reduce methane emissions from Landfills, building sanitary landfills, recovering and recycling wastes and adopting waste to energy technologies.

Policy

Adopt 4Rs: Reuse, reduce, recycle and recovery and aim to provide 100% Door-to-door collection of 100% segregated waste while reducing the waste which goes to final dumping site by 20 percent by 2030.

Strategies

1. Create a sense of Shared Responsibility for waste reduction and management

    - Mandatory segregation of waste at source, in addition to dry and wet municipality should also collect household hazardous waste separately.

    - Conduct Continuous awareness program about solid waste hazardous effects on Health and environment.

    - Encourage people to minimize waste and actively participate in clean-up drives etc.

    - Bulk generators and producer responsibility – shall be the basic principle, promoting the idea that ***"My Waste is My Responsibility".***

2. Reward waste reduction efforts

    - Create incentives for hotels to increase on-site waste management and reduce waste handed over to MCL, with special attention to reducing plastic waste.

    - Provide tax or municipal fee incentives for Zero- plastic hotels or Green Hotels.

3. Implement 100% collection and management of all waste stream

    - Develop guidelines and processes for collecting, transporting and processing of medical and bio-hazards, electronic, industrial, construction and demolition waste.

    - Build facilities with adequate capacity to properly recycle all waste streams to the extent economically and technologically feasible, while capturing all harmful by- products of such processes.

4. Pay special attention to eliminating hazardous materials including plastic

    - Ban burning of garbage within the catchment area of 1 km radius of a residential area.

    - Identify materials that are hazardous to the local environment and prepare and implement a plan for suitable time- bound and progressively stringent restrictions on the sale and consumption of such materials—including certain types of plastics, Styrofoam, coated papers, engineered construction materials, paints and chemicals with heavy metals and so on.

- Work with manufacturers to find alternative materials and product designs to avoid such restricted materials.

5. **Work on reuse of waste – waste to resource projects**

   - Generate clean energy, create composts and recycle paper also recycle construction waste to make construction products such as bricks and sand.

1.4. Water

Climate change and its crisis affects water resources, water infrastructure systems, and agriculture systems. Water is the primary medium through which we will feel the effects of climate change whether through increased incidences of flooding or droughts and exacerbating water scarcity, changes in precipitation patterns intensify floods and droughts, is affecting the quantity of available surface and groundwater.

More efficient use and management of water are critical to addressing the growing demand for water, threats to water security and the increasing frequency and severity of droughts and floods resulting from climate change. Improving access to water is necessary to tackle climate change, innovative, smart technologies are needed to distribute water efficiently and equitably.

The town needs to reduce the impact of climate change on the water system

Assessment

The Leh town and the surrounding villages were completely dependent on natural resources and agriculture for the basic needs, and had a complex and intricate system of water supply through natural springs, canals and ponds, supplying water from the upper glaciers, bogs and springs.

The town had an ample of green spaces and marshes at areas with high water level, with the arrival of tourist after 1970s and 1980s the economy of the town shifted to tourists, agricultural lands have been converted for constructing hotels and guest houses, worsened by low annual precipitation specifically in winter months,

The Khardungla glacier, the predominant source of water for agriculture received low snowfall to sustain the supply of year-around water to the town, over extraction of ground water by residents, hotels, government departments and army reduces the marshes to barren lands.

Water bodies plays a crucial part balancing the biodiversity and urban ecosystem. dZing (pond), yura (canal) and tokpo (stream) are the major part of surface water in Leh town. Since decades ponds in Leh town are used for various purposes, it was initially constructed for agricultural purpose, later it was understood it is best practice in rocky areas for ground water recharge, it was also used as swimming pools.

The melted snow water from the glacier, at some point merges and forms a tokpo (stream) that flows through the town connected by a main channel called mayur (mother channel). Water from the mayur is further diverted into yura (small canals),

which irrigates the fields. The point from where tokpo water is diverted into mayur, and mayur water into a yura is called yurgo; and ska is the point from where yura water is diverted to the field. These have been a crucial part of agriculture in Leh. These were being used since ages for irrigational purpose.

Climate change has a major impact on these water bodies. Uncertain flooding is a major climate change impact we see in the town, which has damaged the stream and the canals and hence affected the irrigation system and water flow pattern. Availability of water in the town is wholly dependent on snowfall. Due to the less snowfall in the recent years surface water as well as ground water level has decreased significantly.

Surface water in Leh town is becoming increasingly polluted. Until couple of decades ago, the residents of Leh would use water coming from the glacial melt through the streams to meet their needs. Around 90% of their needs would be met by this water and for other purposes (10%) they depended on smaller springs (Gyalung, Gangles, and T Trench) (BORDA, 2019). However, in nowadays these streams are no longer fit for consumption.

As living standard of people in Leh has changed they have started adopting more water intensive lifestyle. Such as traditional dry toilet been replaced by flush toilets, shower in bathrooms has become more prevalent. Hence many people have installed private water borewells, legally as well as illegally. According to studies by LEDeG, Leh has approximately between 1500 to 3000 borewells, in an area of 17.2 sq. km., i.e., more than 85 to 170 borewells per sq. km (Anub Tsetan Paljor, 2021). Both PHE and private owners are dependent on ground water for majority of potable water in Leh.

The demand of water is increasing day-by-day, not just for dinking and household purpose but with the degrading surface water system the pipe water supply and groundwater is being extensively used for urban agriculture.

Leh today is almost completely dependent on food imports, and whilst its economic focus has shifted, in a crisis like Covid or with political unrest, food supply can be interrupted. Overall, in Leh, a broader distribution of water, energy and food security related risk would be wise. Thus, in Leh, water, energy and food securities are closely linked. Innovative options need to be explored to support Leh to conserve water and energy, lower its GHG emissions and enhance its adaptive capacity and urban resilience. The question on hand is, how can Leh's ancient future become an alternative climate-proof water future? (Paljor, TUM, & LEDeG, 2021)

Policy

Manage all water resources to use responsibility and protected from pollution, reducing dependency on ground water while ensuring food and water security for future generation.

Strategies

1. Improving understanding of local natural water systems.

    - Conduct a detailed hydrogeochemical study and natural baseline study of Leh's groundwater.

    - Create a detailed GIS map with underground aquifers, surface water channels and bodies, water distribution and sewerage pipelines, borewells, septic tanks and all other related infrastructure, which is updated annually.

2. Water, energy and food security in Leh town – towards a water sensitive town

    To address climate change related water uncertainty and sustainable urban development in Leh holistically, the water energy-food (WEF) Nexus approach is a promising approach for a climate proof water future.

    It highlights that it takes much water to generate energy, much energy to provide freshwater and to collect and treat wastewater, and a lot of water and energy to provide food. Thus, the approach advocates that planning these three sectors in conjunction can support water and energy conservation, and enhance water and food security which are key to human survival. Particularly, wastewater reuse, or rather water reclamation with integrated resource recovery is a key Nexus opportunity (Paljor, TUM, & LEDeG, 2021).

    Resources that can be recovered from wastewater include water for various re-use options such as agricultural irrigation or groundwater recharge, bio-energy and nutrients. Further, resource recovery can be facilitated through decentralized systems, in which resources are less diluted.

    - Implement a pilot project for innovative wastewater management through decentralized water reclamation with resource recovery in the town where centralized sewage system is not connected, to enable water and energy conservation and support resource recovery.

    - Water reclamation and reuse is an integrated approach that strives towards a circular system to enable a more sustainable water supply.

    - Implement constructed wetland technology, it is the most suitable option for decentralized water reclamation with resource recovery in Leh: this is a type of Nature-Based Treatment System (NBTS) which simulates natural ecosystem mechanisms for water treatment.

    - Manage aquifer recharge and groundwater protection measures suing soil aquifer treatment.

    - Implement and introduce low energy, water sensitive urban farming systems and techniques.

    - Plan and set up urban design and planning guidelines that uses low energy and water.

- Integration of institutions, by instating a cross-departmental WEF Nexus taskforce of 6-8 persons who meet at regular intervals to discuss WEF Nexus implementation steps and related tasks.

- Multi-stakeholder participatory process implementation to get the local community involved.

- Implementation of the Nexus approach in Leh can build on reinventing the role of Churpons as Nexus or resource recovery managers

3. **Expand and improve the piped water system to reach all users and improve service levels**

    - Prepare detailed maps of unserved areas and project future growth of the Town.

    - Create a road map for expanding the system to reach unserved users, and mechanism to set targets and monitor progress.

    - Appoint expert consultants to create a roadmap for upgrading the water network to deliver 24x7 water supply throughout the year, and ensuring properly O&M to minimize costs and maximize asset life.

1.5. Urban ecosystem

All of the impacts of climate change have direct or indirect consequences for urban ecosystem. Climate change and urbanization are likely to increase the vulnerability of biodiversity hotspots, urban species, and critical ecosystem services. The urban ecosystem have a important role in helping cities mitigate the impacts of climate change, harnessing urban ecosystems as adaptation and mitigation solutions will help achieve more resilient, sustainable and liveable outcomes for the city.

Investing in the quality and quantity of urban ecosystems and green infrastructure has multiple co-benefits, including improving quality of life, human health, and social well-being

Assessment

According to Pickett et al. (2001), urban ecosystems are those where people live in high densities or those where the built infrastructure covers a large proportion of the land. The infrastructures in these areas incorporate both planted vegetation such as urban forests, parks and gardens and water bodies like ponds, small lakes and wetlands. However, in a broader sense, areas around the cities, anyhow linked to or directly managed and affected by material and energy from core urban or suburban parts, are also components of urban systems (Pickett et al., 2001). There are various factors, such as population density, overall population, proximity or distance between urban dwellings and land-use patterns and employment outside primary sector, that determine the urban areas between countries or states (Gómez-Baggethun and Barton, 2013).

Following are the major elements of Leh town's urban ecosystem:

1. Wetlands (Bogs)
2. Agricultural fields
3. Water bodies
4. Woods
5. Kitchen gardens
6. Parks

Wetlands, waterbodies and agricultural fields have greater role to play in urban ecosystem in case of Leh town as they cover significant area of the town. While woods, gardens and parks play crucial role in balancing urban ecosystem.

Wetlands and bogs are witnessing the impacts of climate change and urbanisation in the town , Wetlands are very important elements of the biodiversity and urban ecosystem. Bogs are the most common type of wetlands in Ladakh. Bogs are characterised by acidic waters and spongy peat deposits as well as a covering of sphagnum moss. Bogs tend to get their moisture from precipitation rather than waterways such as streams or stream runoffs. Less precipitation in the recent years, in addition to over-extraction of ground water has led to the drying-up of the wetlands. These wetlands are ideal for preventing downstream flooding and therefore need to be conserved. There are nine major bogs in Leh town. Since 2019, people in Leh have gained access to more information on wetlands and it has been used for various recreational purposes. The following are the major wetlands of Leh town:

1. Major wetlands
2. Gyamtsa Spang
3. Gangles Spang
4. Chorten Spang
5. Gompa Spang
6. Khakshal Spang
7. Yurtung Spang
8. Chubi Spang
9. Skara Spang

Presently the green cover of Skara spang has almost become the half since the year 2003. According to geo-spatial data in the year 2003, the area of green cover of Skara spang was 13 hectares, which decreased to 9 hectares in the year 2010, which has further decreased to 6 hectares in 2020. The main reason of the decline in green cover is ground water depletion, followed by construction works in and around the bog.

Agricultural fields play an important role in balancing the urban ecosystem. It can an important role in balancing carbon content in the air, by minimizing agricultural greenhouse gas emissions and maximizing carbon storage. According to the geospatial data there was 406 hectares of area under agricultural use in the year 2003, 40% of which is now converted to other uses such as residential and commercial, mainly tourism, again according to satellite and anecdotal data.

Woods are another important element of urban ecosystem. A wood is defined as an area of land, smaller than a forest, covered with trees. According to the above definition, there are total 3 woods in Leh town, these are:

1. Skyatsags bhag
2. Bhadame bhag
3. Dambuchan bhag

Domestic or kitchen gardening is a common practice in Leh town. Most of the households have kitchen garden while rest don't have because of lack of land in some areas such as housing colony, skampari, murtse, agling, skalzangling etc. Domestic gardens constitute a substantial proportion of 'green space' in urban areas and hence are of potential significance for the maintenance of biodiversity in such areas.

There are only three town-level park and few neighbourhood-level parks in Leh town. Parks also constitute a substantial proportion of 'green space' in urban areas and hence are of potential significance for balancing urban ecosystem.

Policy

Conserve and expand the natural water system of wetlands, water bodies and channels throughout the town, while using it for recreational and urban design elements in sustainable way while increasing the green cover in the town through parks and bogs.

Strategies

1. **Invest in ecosystem-based adaptation and green infrastructure planning as a critical component of climate adaptation strategies and urban development but also for improved health, disaster risk reduction, and sustainable development.**

2. **Re-establish and improve water management and resilience practices**

    - Develop town-wide and ward-level institutional mechanisms that involve communities in monitoring and protecting water resources, including re-establishing traditional practices like the Chirpon system.

    - Develop a holistic research programme to monitor the natural water systems and watersheds in and around Leh, and use the data to both predict future shocks and identify opportunities to support the natural water system.

3. **Re-vitalize and expand the network of natural water bodies in Leh**

    - Revitalize and expand existing zings and yura, and identify locations where new ones can be developed, while integrating beautification elements and green spaces.

    - Restriction of construction on existing bogs and agricultural areas.

    - Encouraging domestic gardens

4. **Properly Develop and Manage Natural and Green Spaces**

    - Properly Develop and Manage Natural and Green Spaces

    - Develop green public spaces such

as parks and playgrounds, as well as water bodies

- Ensure proper maintenance and optimal use of all green spaces, whether privately or publicly owned.

5. Maximize bio-diversity and its benefits

- Study and implement ways to maximise bio-diversity of local species.
- Focus on plants and animal species that create a healthy and resilient environment, and provide medicinal benefit
- Construction bye-laws and zoning must be used to achieve these strategies.

1.6. Disaster risk management

Assessment

"Glacier and Snowmelt decline has altered the frequency, magnitude and location of most related natural hazards (high confidence). Exposure of people and infrastructure to natural hazards has increased due to growing population, tourism and socio-economic development (high confidence)" – (IPCC Special Report on Oceans and Cryosphere, 2019)

Recent studies show that temperature increase in the Himalayas over the past 100 years has accelerated much faster than previously predicted. Warming has had significant effect on the region's water resources, most visibly with the retreat of glaciers and snowpack, unseasonal snow melting, and several floods in the past few years usually accompanied by mudslides that destroy homes, farms, bridges and roads, and cut off villages from communication and assistance.

The mountain ranges of Ladakh were created about 45 million years ago as the Indian plate drifted into the Eurasian plate. This movement continues, resulting in the Himalayan mountains growing taller with time, but also causing frequent, mild earthquakes (mostly 3.5-5 on Richter scale—3.6 in Feb-2020, 4.6 in Jan-2020, 4.4 in Jun-2018, 5.4 in Dec-2017) but scientists are warning of stress build-up that could result in even more severe earthquakes than the 7.8 scale one that hit Nepal in 2015.

It is commonly expected that natural disaster will probably increase in intensity and frequency, and better systems are needed to predict and prepare to reduce losses to minimum, and bounce back as quickly as possible after such an event, physically, emotionally and financially.

Not enough has been done to protect the town from future disasters, making the below strategies and actions absolutely critical to protect life, assets and the environment. Advance warning systems are required, clear protocols should be in place for people to follow in such situations and no single department or office is responsible for planning or implementing measures for resilience.

Strategies

1. Revise and Update the existing Disaster Management Plan for Leh

    - Conduct detailed risk assessments for different parts of Leh and surrounding areas for various types of disasters, and establish a process to update this study every five years.

    - Implement suitable advanced detection and early warning systems including public broadcast mechanisms (using loudspeakers, SMS messages, door-to-door message systems, internet, radio and television) based on relevant international practices and The National Disaster Management Act 2005.

2. Implement measures to prevent disasters and mitigate their effects

    - The risk assessments must be used to amend zoning rules, construction norms and development plans, and create infrastructure that reduce the risks of disasters

    - Conduct regular trainings and practice drills periodically, with particular attention to the post-disaster recovery phase

    - Ensure a stockpile of emergency materials including medical, food and sanitation supplies, and funds with local authorities to deploy specifically in such situations.

Executive summary

Following policy strategies are proposed for mitigating and adapting the climate change in Leh town

1. Develop a comprehensive and eco-friendly urban mobility plan, that focuses on sustainable public transport system supported by a pedestrian and cycle friendly environment.

2. Introduce and implement Low carbon space heating technologies and prioritize efficient homes and mandatory room insulation in the building codes.

3. Adopt 4Rs: Reuse, reduce, recycle and recovery and aim to provide 100% Door-to-door collection of 100% segregated waste while reducing the waste which goes to final dumping site by 20 percent by 2030.

4. Manage all water resources to use responsibility and protected from pollution, reducing dependency on ground water while ensuring food and water security for future generation.

5. Conserve and expand the natural water system of wetlands, water bodies and channels throughout the town, while using it for recreational and urban design elements in sustainable way while increasing the green cover in the town through parks and bogs.

6. Prepare a robust and advanced disaster detection and early warning system for floods, earthquakes and other natural disaster, with effective disaster response plans and agencies.

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Ladakh Ecological Development Group (LEDeG
Karzoo,Leh,
Ladakh 194101,
India
T : +91-1982-253221; +91-1982-252284
mail@ledeg.org
www.ledeg.org
www.lehvision2030.com

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