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PUNE INTERNATIONAL CENTRE

Making Pune Metropolitan Region Carbon Neutral By 2030

A Policy Roadmap

January 2020

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(Energy, Environment and Climate Change)

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The work in this paper is a synthesis of more than a year-long research, interactions and brain-storming with many experts and concerned citizens. This study provides a roadmap that can make Pune Metropolitan Region (PMR) Net Carbon Neutral by 2030. This report represents the collaborative effort of a knowledge partnership group formed as 'Climate Collective Pune' under the umbrella of PIC.

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Prof Amitav Mallik
and Team EECC

Policy Roadmap: Making PMR Carbon Neutral by 2030

CONTENTS

ANNEXES

Introduction

Twenty-nine years since the UN Earth Summit in Rio (1991), it is amply clear that global warming and the resulting climate changes have emerged as the most dangerous existential threat to human health, well-being and progress. Ironically, the main cause of this is the exploitation of Earth's resources, particularly the increasing extraction and burning of fossil fuels and serious deforestation worldwide by the modern civilization for its energy needs, development and progress. Today the ecological footprint of over seven billion humans has become so large, that it is threatening the intrinsic stability of the 'Earth Ecosystem' that is so vital to all life.

Carbon dioxide equivalent (CO_2eq) gas concentration has reached 410 PPM *(compared to pre-industrial average of 280 PPM)* and is continuing to increase at 2 PPM every year. At the Paris Conference in 2015, over 190 countries agreed on serious voluntary commitments to reduce greenhouse gas (GHG) emissions, but there is still no sign of real global emission reduction. Concentration of greenhouse gases (GHG) if un-checked, will cause unprecedented global warming and make most parts of the Earth un-inhabitable for human life within this century.

Carbon Dioxide is an invisible and odourless gas that stays in the atmosphere for centuries. Although it is an important part of the carbon cycle which is essential for life – beyond a certain concentration, it must be treated as hazardous due to its undesirable heat-trapping effects. Rapid heating of atmosphere due to greenhouse gases (GHGs) may create regenerative feedback effects in the Earth ecosystem called 'tipping points', beyond which, even the best of human efforts may not be adequate to reverse the process. They may cause multiple simultaneous extreme events and challenge the very survival of human and most other living species.

With just over 1°C warming *(above pre-industrial average) c*limate change effects are already visible in the form of rising heat, unusually heavy rains and flooding, intense and frequent cyclones and an alarming rate of melting of polar ice-sheets. It can raise sea-levels to drown most coastal cities around the world. Globally school children are protesting against lack of timely Climate Action by Governments and political leadership. In India, climate change is already causing heavy economic losses, and will further damage the economy, security and human health in future.

The desired global action to combat climate change requires moving away from the fossil-fuel dependent economy. But it is not yet happening due to the concerns of economic slowdown. However, recent analysis indicates that delay in climate action would cause far bigger economic losses in future, if urgent actions are not taken now. The present model of limitless growth with limited Earth resources is not sustainable and a transition to clean energy is a must. Low-carbon economy will offer a unique opportunity for the human

civilisation to not only avert an impending climate catastrophe but also remain competitive for future of human development.

Although climate impacts will be global, a tropical country like India will be far more vulnerable to it than the colder and high latitude modern countries. At the Paris Climate Summit, India made significant NDCs for reducing the carbon intensity of development to 35 % below the 2005 level, so that the pace of economic development can be maintained without hurting the environment. While combatting climate change will require well-coordinated global action, it must all start with local actions. This will require urgent moves towards lower carbon footprint for all development activities, for which major cities of India like Pune must take pioneering leadership.

PMR (Pune Metropolitan Region) is a fast-growing urban conglomerate with a large area of 7,256 sq.km, and a population of over 7.2 Million (2018), which may grow to over 10 Million by 2030. It is ideally suited for establishing sound climate-resilient planning with environmentally best-practices to achieve 'Net Carbon Neutrality' by 2030. While this paper is an effort to chalk-out a pathway to achieve this, implementing the recommendations will undoubtedly require radical measures, unlikely to be palatable to the common man who is too engrossed in the present. Generating proactive response to the climate catastrophe, even if realized in principle, cannot catch momentum unless someone can demonstrate the do-ability by taking bold steps.

This paper endeavours to nudge the PMRDA to take up the challenge. Pune (PMR) must initiate pioneering efforts to Achieve Carbon Neutrality by 2030 and provide a replicable model for other Indian cities, to eventually make India carbon neutral, hopefully, by 2047 – the 100th years since our independence.

FRIDAYS FOR FUTURE

In 2018, the then 15-year-old Climate Champion and Activist, Greta Thunberg from Sweden, started Climate Strike alone. She was eventually joined by millions of students all across the globe. They have together formed 'Fridays For Future' Movement (https://www.fridaysforfuture.org).

These responsible global citizens organized Global Climate Strikes with participation from millions of people across the Globe, simultaneously striking in more than 120 countries and around 2000 cities on the same day including many cities in India.

Executive Summary

It is important to note that achieving 'Net Carbon Neutrality' for PMR by 2030 is indeed entirely doable, if majority of citizens and political leadership can be motivated to take radically bold steps to protect the future of their children and grandchildren.

In 2018, the total CO_2eq emissions of PMR were 26,061 KT (Kilo-Ton) and total capacity for sequestration was about 779 KT. Hence the 'Emission Gap' was 25,281 KT. Well planned urgent actions over next 10 years must reduce the total annual emission in 2030 to match the enhanced level of total natural carbon sequestration capacity of PMR. If that gap is small, then the technology-assisted CO_2 removal capacity can perhaps help achieve net-carbon-neutrality at an affordable cost.

Major Observations and Recommendations are summarised here

1. *First priority must be a rapid transition to Renewable Energy (RE) and drastic reduction of Coal-Oil-Gas use. Global Oil industry is very powerful and will resist change. Limiting climate impact is a worthy cause. Government subsidy to Coal-Oil sector must be stopped and* ***funds diverted for climate mitigation actions****.*
2. *Equally important will be to rapidly increase the RE capacity so that the energy transition need not hurt the economy. Fortunately, RE is now competitive even without subsidy and RE based life-style will actually help build new economy as well as create new jobs.* ***RE must become the 'New Oil' of the future.***
3. *For PMR, major areas for change are those within its jurisdiction.* ***PMR must maximise energy efficiency and minimise wastages across all sectors****. This can be achieved in steps with people's movement and governance reforms.*
4. *PMRDA must maximise the use of distributed RE generation (Roof-top) using solar, wind and biogas within its jurisdiction. This offers double benefits – replacing polluting energy with clean RE and* ***building indigenous RE capacity for ultimate energy independence.***
5. *Solar farms over just 10% of total PMR land can meet the entire electricity demand of the region with custom designed Microgrids and advances in battery storage technology. This can create indigenous clean energy abundance and* ***accelerate progress without any economic slow-down or any penalty to the Earth environment****.*
6. *PMRDA must evolve its own* ***ambitious 'Green Building Codes' and norms for biodiversity protection. PMRDA must ensure 100% compliance*** *by all new construction activities starting 2020. Violation of norms by Builders has been the main cause of Cities in decline and* ***this must change on absolute priority****.*

7. *PMR must **additionally reserve 10% of its total land for ecological restoration** for enhancing the region's capacity for carbon sequestration.*
8. *Innovative R&D for artificial sequestration and CO_2 emission removal must also be initiated in collaboration of industry leaders to bridge the shortfall in natural sequestration capacity.*
9. *All new developments in PMR should be based on cluster of **small modular green townships, each designed to be carbon neutral within itself.** The region can thus emerge as a model for sustainable future for all Indian cities.*
10. *All new industries in PMR region must be mandated to be carbon neutral from the start. Existing **industries must become 'net carbon neutral' by 2025**. This is entirely doable. PMR must enact local legislations for strict compliance with heavy penalty for defaulters.*
11. *PMR should build a cadre of trained manpower for creating the green-clean culture and **demonstrate that going green makes good business for future**. Hopefully this would build new leadership for a sustainable eco-friendly future.*
12. ***Educating women about the importance of preserving environment and limiting climate impacts** needs to be incentivized to build a new generation that can be much better tuned to be in harmony with the natural environment.*
13. *For PMR to become 'Net-Carbon-Neutral' in 10 years, it will require several bold and coordinated transformational changes. This must have people's involvement. **A new 'Empowered Citizen Committee' with eminent city elders must be formed to advice and monitor timely execution of milestones** on the road to carbon neutrality.*
14. *PMR must **embrace the shift to low-carbon economic development model** and demonstrate that sustainably smart development for economic progress, can go hand-in-hand with aggressive climate mitigation actions.*

This policy paper highlights the results of the study undertaken by the EECC team of PIC to analyse the available environmental data and information on Pune Metropolitan Region (PMR) for defining a strategic policy roadmap for Pune to become the first Indian city to be 'Net-Carbon-Neutral' by 2030.

To limit global warming to under 2^0C, global cumulative emissions from now to 2050 must be less than 1000 Giga-Tons (GT) and the net global emissions must reduce to net-zero by 2050 to stay below 2^0C. Present trend of addition of over 50 GT per-year of CO_2eq emission must be effectively reduced to 33 GT per year, STARTING NOW.

Chapter 1. Carbon Neutrality for PMR by 2030

1.1. Climate Action Urgency for Cities

The Inter-Governmental Panel on Climate Change (IPCC), in its October 2018 report declared, that atmospheric CO_2 concentration had already crossed 410 PPM and the window of opportunity to avoid 'Catastrophic Climate Impacts' would only be till 2030, the next 12 years. IPCC also warned that without serious and urgent climate mitigation action, our planet will be on a path to 4°C warming by 2100 and even worse beyond, which would mean that babies born now would face very hostile environments when they become senior citizens. Scientists also confirm that the rate of change in Earth's climate observed to date, is much faster than predicted by IPCC's conservative reports. In an 11thSept 2019 report by UNSDG – 'The Future is Now', scientists call for urgent targeted global action, to avoid reversing the development gains of recent decades. This confirms that climate change has already become an economic concern and timely action would ensure double benefits.

Given the complexity and inter-connectedness of the Earth systems, it will be impossible for any individual or community to escape or evade the impacts of climate change. We need to realize and respect that we affect the environment we live in just as it affects us. We must unite as responsible global citizens to mitigate further emissions and quickly adapt to face the climate changes that are no longer avoidable. We need to think globally but act locally, to reduce GHG emissions of all urban areas to successfully lessen the total emissions. Cities being more responsible for this predicament must take the lead in climate mitigation and adaptation actions. Many cities have already commenced initiatives to achieve early net carbon neutrality like– Copenhagen is aiming to be carbon neutral by 2025.

Carbon Dioxide is an invisible, odourless and cumulative gas that stays in the atmosphere for centuries. While the carbon cycle is essential for life, beyond a certain concentration – it needs to be recognized as hazardous because it causes undesirable heat-trapping effects that, if un-checked, can cause unprecedentedglobal warming and make most parts of the Earth un-inhabitable for human life. Rapid heating can also create regenerative feedback effects on the Earth ecosystem, called 'tipping points' beyond which even the best of human efforts may not be adequate to reverse the process. This can cause multiple simultaneous extreme events and challenge the very survival of human species. Environmental

Cities that occupy only 2% of the earth surface, will soon have around 60% of the total population and contribute to more than 70% to the GDP growth. Being heavy energy consumers as well as the largest generators of waste, they would also emit maximum greenhouse gases (GHG) amounting to over 70% carbon emissions. Hence cities globally must take initiatives to achieve Carbon Neutrality – like Copenhagen is planning to do by 2025. A City is a place where maximum human energy and far-reaching thought processes exist and it is also a place where people can bring about big differences to tackle climate change. This can be achieved by focusing on important sectors such as electricity, transportation, land-use, construction, water and waste management and overall urban planning. The importance of conserving the natural ecosystem for carbon sequestration and the technological innovations for creating artificial carbon sinks for offsetting the emissions can also happen in the innovation centres in a city.

The result of not acting against climate change in recent decades is already causing serious losses to ecosystems, land availability, businesses, property, and human life. It is now well accepted that every dollar invested now on timely climate action, would likely save over 7 USD by 2050. Climate Change action needs to receive momentum and importance at every level – individual, community and government. Despite extended international political debates, actual action at the ground level by various government leadership remains low. Youth all over the world are already staging protests against the lack of climate action by governments across the world.

Indian cities will be among the first in the world to suffer badly. It is therefore very urgent that each city in India must contribute its best to move towards Carbon Neutrality which would also improve its Climate Resilience in the future.

1.2. Why PMR ? – Scope and Challenges

India's CO_2eq emissions are growing at a faster rate than any other major energy-consuming nation. It is largely because of continued heavy dependence on coal-powered thermal plants for electricity generation, and the use of fossil fuels for all transportation and industry requirements. In 2018, India was the 4th largest emitter, accounting for 7% of the total global GHG emissions. Furthermore, the country's total emissions rose 4.8% from the previous year, according to a new report by the Paris-based International Energy Agency.[(Ref1)] However per-capita emissions are still at about 40% of the global average.

Urban areas, including small towns and major cities, contribute over 70% emissions in India. It is estimated that the per-capita emissions in urban Indian households can be 16 times greater than their rural

[(Ref1)] International Energy Agency, (2019), Global Energy and CO_2 Status Report, https://webstore.iea.org/global-energy-co2-status-report-2018

counterparts – almost equalling modern global cities. Thus, affluent urban areas have a higher responsibility to reduce national total emissions. This is why Pune, being the cultural and knowledge capital of Maharashtra, must recognise this responsibility and take a leadership role in achieving net carbon neutrality at the earliest.

Pune Metropolitan Region (PMR) is considered to be one of the fastest-growing urban conglomerates in the Asia-Pacific region. Currently, it is the 8th most populous city in India with over 7 million population, which is expected to grow to over 12 million by 2030.[(Ref 2)] Pune is known for its friendly climate, well suited for Pensioners. However, with increasing population and expanding concrete constructions, it is getting hotter - requiring air-conditioning systems for comfortable living. Hence, Pune region has an opportunity of restoring the Climate-friendly neighbourhood by first learning to reduce its per-capita energy demand and simultaneously shifting to Renewables like rooftop Solar power generation to become a city with Climate-Smart Development.

The city of Pune is well known for its diverse educational and cultural organizations and its large number of manufacturing and IT industries, making it an energy guzzler. Evolving an adequate clean energy infrastructure for the increasing energy demand, and efficient water & waste management in Pune district can go a long way towards preserving the natural environment. Achieving 'Carbon Neutrality' in 10 years may sound like an ambitious goal; but for PMR, that takes pride in being very pragmatic, it should not be very difficult to become highly climate-sensitive. The region can take appropriate climate action if conducive policy framework is established for pioneering the desired transformational change.

PMR is spread across 7,256.46 sq. km. and comprises of two Municipal Corporations of Pune and Pimpri Chinchwad, three Cantonment Boards, seven Municipal Councils, 13 census towns and 842 villages and most of it falls under 'Greenfield Development'. The Pune Metropolitan Region Development Authority (PMRDA) is set up to facilitate the planned growth of infrastructure and public services, enhance the ease of doing business for domestic and international investors and develop a system of futuristic governance and a market-based economy. The region must promote Green innovation with e-management and digital information dissemination. It must generate sustainable employment and wealth creation opportunities for all its citizens. It should integrate culture and heritage into the very ecosystem of PMR and consistently promote a higher 'Happiness Index' for all of its people.[(Ref3)]

To achieve this, it is important to annually track the GHG emissions and prepare an inventory of the current emissions scenario for PMR. This will help to analyse trends and identify potential areas to drastically reduce the region's Carbon Footprint.

[(Ref 2)] *R. Krishnamurthy et al (2016), City profile: Pune, India, Cities, 53: 98-109.*
[(Ref 3)] *PMRDA Website http://www.pmrda.gov.in/*

These suggestions need to be included in the Comprehensive Development Plan by PMRDA, to adopt low-carbon practices and achieve Net Carbon Neutrality by 2030. The co-benefits of these practices include local income generation, circular economy, less environmental degradation and pollution.

As per the PMC Environment Status report 2018 (ESR), the city's average per-capita emissions have increased by 12% from 1.46-tonne carbon dioxide equivalent (tCO_2eq) in 2012 to 1.64 tonne in 2017, a rise within 5 years.[(Ref4)] This rising trend, if not checked urgently, will seriously add to national total emissions and contribute to climate change effects. Pune also needs to develop resilience towards impacts of Climate Change, as the city is already witnessing a rise in maximum summer temperatures and irregular monsoon. This paper aims to set specific time-bound goals for Pune region to become 'Net Carbon Neutral' by 2030.

Table 1. Emission Gap Estimates

Scenario	PMR Emissions	Carbon Sequestration	Emission Gap
Current (2018)	26,061.29	779.83	25,281.46
Business-as-usual (2030)	64,607.86	1569.84	63,038.02
Aggressive Climate Action (2030)	7733.52	2,021.39	5712.14

*All values expressed in Kilo-Ton CO_2eq/year

This shows that aggressive climate action can bring down the emission gap to about 4493 KT, (instead of 63828 KT) which may be a practical and affordable target for artificial removal of CO_2 from the atmosphere, with technological solutions that are expected to become mature by 2030.

Assumptions*:*

- Current data from 'Baseline Emissions Report 2018' for EECC Project (PIC)
- Business-as-usual (2030) emissions calculated using same emission intensity and factoring in 6.3% per year GDP rise and 1860 sq.km. forest cover as proposed by PMR (from Citizen PMRDA presentations)
- Aggressive Climate Action (2030) calculated by considering 80% reduction in Scope 1 and 2 and 50% reduction in Scope 3 current PMR emissions and forest cover increase to 33% of the total PMR land area (including existing 15%)

[(Ref4)] *Environment Status Report, 2018, PMC*

1.3. Climate Smart Development

While most of the past urban development concentrated on rapid economic growth targets, with stress on modern lifestyle enhancement for the citizens, the new reality of a 'Climate-Challenged World' will demand much more attention to environmental and ease of living parameters. That will call for stricter compliance with environmental protection codes for all activities. All new structures must conform to the latest ECBC Green building codes, which must seek an optimum contribution from low-energy demand architecture, rooftop solar electricity generation, rainwater harvesting as well as an in-built capacity for effective water and waste management. These will be crucial attributes of the future modern Urban Centres.

While discussing the potentials for environment-friendly planning for PMR, it is important to assess the scope and challenges in the implementation of ambitious plans. The proximity of knowledge-centric institutions around PMC and the IT hub of Hinjewadi, along with the automotive and manufacturing complexes around PCMC, makes the PMR region very attractive for robust wealth generation through rapid economic growth. It would be very natural to put the environment and climate change agenda on the back burner in the atmosphere of vibrant economic progress. Hence it is important to remember that any delay or neglect of environmental priorities will cause many-fold losses in the future to the same economic aspirations that are driving the progress today.

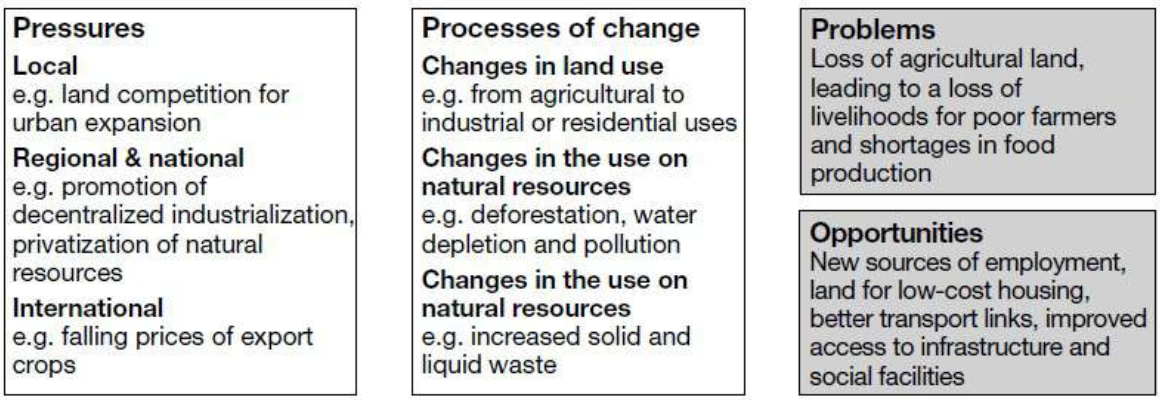
Achieving carbon neutrality in a changing Earth-ecosystem that will most likely get increasingly hostile, will require clear long-term attention to real priorities of sustainable growth. Short-sighted policies for a quick return on investment must be replaced by a more prudent approach for long-term sustainability. For achieving carbon neutrality under more stressful conditions, it would be important to annually track GHG emissions and prepare an inventory of the current emissions scenario for the entire PMR region. This will help analyse emission sources and trends, and thus, help in identifying focus areas to drastically reduce the region's Carbon Footprint. To understand the scope of the challenge, this paper attempts to analyse some available information on PMC, PCMC and PMR.

The PMR occupies a large area with diverse settlements including urban, rural and peri-urban regions. From an environmental perspective, the peri-urban interface can be characterized as a heterogeneous mosaic of ‘natural’ ecosystems, ‘productive’ or ‘agro’ ecosystems and ‘urban’ ecosystems affected by the material and energy flows demanded by urban and rural systems. Geographical and administrative boundaries prevent a strategic approach to environmental planning and management of these regions and hence becomes challenging (Figure 1).

Efforts to build resilience to climate impacts – including frequent droughts, stronger storms, changing rainfall and failed harvests – aim to ensure families, communities and governments can manage and bounce

back from them. Sound development policies are needed to build climate resilience by building people's adaptability to socio-economic and climate-related shocks. Policies must lead the way towards achieving the kind of transformations required to build inclusive and climate-resilient societies. Sometimes just making citizens, and not just planners, more aware of the growing risk of shocks and that something can be done to prepare, helps in disaster risk reduction and disaster management.

Figure 1 : Processes of Change in Peri-urban regions



The challenge is centred on the adoption of national policies which will, within each country's context and constraints drive efforts towards poverty eradication, human development, and climate resilience. Those who are the most exposed and vulnerable are also the ones who are economically and socially disadvantaged and the least likely to have access to support systems. Thus, given the absence of government support, even small changes in temperature or rain and wind patterns can push people into poverty traps.[(Ref 5)] Climate resilience demands that social, economic and ecological systems become capable of reorganizing to maintain their essential functions, identity, and structure, while also maintaining their capacity for adaptation, learning and transformation. The PMR covers the mountainous region, river basins and plateau region. Hence building resilience becomes crucial for economic success.

Planning must involve the following processes and specific solutions to achieve the required targets.

- Map environmental assets, land-use, and natural resources regularly to determine emission-reduction targets, climate change adaptation measures and time frames for the climate-neutral transition.
- Evolve a Climate Action Plan with 2-year time-frames for climate mitigation & adaptation up to 2030 and beyond.

[(Ref 5)] *Olsson et al, (2014), Livelihood and Poverty, Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[Field, C.B., V.R. Barros et al].*

- Enhanced climate awareness for conveying the urgency of Climate Action at all levels.
- The Carbon Footprint for essential infrastructures serving cities should be calculated using accounting methods which include indirect (Scope-3) emissions like the Trans-boundary Infrastructure supply chain Footprint (TBIF) as tried in Delhi. [Ref6]
- Use traditional knowledge practices like 'Sacred Groves' which serve as seed banks for native vegetation
  Include continuity of local vegetation and animal corridors, using landscape matrix studies, in development plans
- Promote, develop, safeguard or retrofit green and blue infrastructure (for water management) while improving grey (hard) infrastructure to address biodiversity outcomes
- Restore, enhance and conserve ecosystems and corridors, especially forest cover on slopes of Western Ghats and in Catchment areas using landscape planning for better Climate Resilience
- Plant native trees or retain wilderness patches along Roads and increase tree density in building premises. Palms may be planted additionally but only native woody medium or large-sized treesshould be used for plantations and gardens.

1.4. Net Carbon Neutrality – An Economic Perspective

Human development over the past centuries has been dependent on natural resources and technological advances, but the rate of development earlier was well within the capacity of the nature to absorb. However, ever since the Industrial Revolution about 200 years ago, the level and pace of exploitation of nature by the modern human civilization has been growing to a level that is rivaling and even overwhelming the natural processes. It is becoming clear that such limitless growth aspirations cannot be sustained given the limited resources of the Earth. The consequences are visible in the form of frequent climate disruptions causing significantly reduced finances for supporting growth objectives. Chasing further growth or progress by following the same economic models is thus becoming economically unviable.

While the more visible climate impacts like cyclones or forest fires are less predictable, another kind of climate impact that is less visible but is getting more certain is due to the slow and invisible nature of CO_2 emission accumulation and global warming. It is certain to disrupt all economic activities of the future, the signs of which are becoming perceptible now. These include increasing precipitation due to a rise in average temperature, increasing floods and droughts and rising sea-levels due to receding polar caps and glaciers. According to the International Institute for Sustainable Development, India is among the top 15 countries that are vulnerable to climate change. To prevent unproductive investments in relief work and redevelopment as a result of catastrophic disasters, climate action with sustained economic growth is a must.

[Ref 6] *Chavez, A., et al. (2012),Implementing trans‐boundary infrastructure‐based greenhouse gas accounting for Delhi, India, Journal of Industrial Ecology, 16(6), 814-828*

The vulnerability of poor people to natural disasters, especially floods, droughts and heat-waves is already seen in India. The most recent example is the damage caused by floods in Maharashtra including PMR, largely magnified by encroachment and mismanagement of flood-lines. Such disasters aggravate the problem of poverty and puts in motion the undesired cycle of poverty low income low demand and consumption low investmentslow production low growth.

Today, India is witnessing one of the fastest rural-to-urban transitions in human history, with the numbers increasing to over 200 million by 2030, which would require infrastructure development costing billions. About 70% of the infrastructure required in 2030 is yet to be built. Energy consumption, particularly electricity will double, perhaps triple, by 2030. Since, energy is the major input to most of the economic activities; it is a potential area where the change for sustainability and a cleaner future can begin. If the investments in the sector are made by a policy and private sector shift to renewables to meet the majority of the energy demands of the country, it will prove to be economically profitable in the long run.

Therefore, the solution for a planned transition to a low-carbon economy is based on renewable clean sources. But the momentum for such a transition is hampered by wrong perceptions that moving away from established fossil-fuel economy may hurt development. However the reality is that coal, gas, oil and petroleum products are and will become more expensive besides further damaging the Earth systems to catastrophic levels. Conversely, the Renewable Energies (RE) that are already competitive will get more affordable while protecting the environment at the same time. Industries have the greatest incentive of shifting to within country generation of renewables that offers self-sufficiency on the energy front. means reduced costs and increased profitability. India with one of the largest youth population needs to be assertive in promoting RE technologies for a sustainable future. Thus, going Carbon Neutral has huge implication for the future of Indian cities.

On the production front, stresses such as Heat and Water Stress arising out of changing climatic conditions have a negative impact on the economic productivity. Lower productivity and human well-being are indeed undesirable from the perspective of economic growth and thus undertaking climate change adaptation and mitigation actions are a clear priority to ensure economic security. On the demand side, economic incentives of the consumers also need to change to facilitate a path towards cleaner economic activities. A properly informed consumer base with aligned interests for buying products with less carbon footprint through policy nudges, can shift the entire production process towards cleaner modes.

Today, we are on the cusp of a new economic era: one where growth is driven by the interaction between rapid technological innovation, sustainable infrastructure investment and increased resource productivity. It will result in efficient and live-able cities that are low-carbon, with smart and resilient infrastructure. This would also help in restoration of degraded lands while protecting valuable forests. If we do not wake up to the

need of the hour to realign our priorities, it will not only lead to a major economic slow-down but also accelerate climate catastrophe for the younger generation. It is thus within the economic interest of the country to aggressively act towards mitigating and adapting to climate change.

Chapter 2
Development Priorities for PMR

Chapter 2. Development Priorities for PMR

The steady rise in frequency and intensity of extreme weather events combined with a perceptible rise in summer temperatures all over the world has enhanced the awareness of global warming and climate change to over 65% of the people across the world and the need for urgent climate mitigation action is being recognized more widely. Despite climate change denial by the US President and his administration, many cities and countries concerned with climate change are increasingly setting goals for a transition to a carbon-neutral economy.

The new 'Carbon Neutral Cities Alliance' (CNCA) is a collaboration of leading global cities working to cut greenhouse gas emissions by 80-100% by 2050 or sooner. To date, this CNCA includes 20 metropolises with progressive cities like Copenhagen, Denmark set to become the first carbon-neutral city by 2025. Increasingly city authorities are emphasizing that such a goal is indeed realistic.

Some of the urban low-carbon innovations today include use of IoT for reducing energy demands, net metering for spreading of rooftop solar, stricter vehicle emissions standards to reduce air pollution, electric cars and busses, even RE-powered trains and boats to cut down emissions. Almost all of them are driven by regional or local governments through regulation, policy, or investment. These aren't free-market or Silicon Valley digital plays, but real-world urban planning priorities.

As brought out in the previous chapter, Pune Metropolitan Region (PMR) in its initial development phase represents a unique opportunity to evolve as a modern urban complex with carbon-neutral development priorities. As Climate Change measures are concerned with the climate, location, urban sprawl, types of economic activities, etc. all Indian cities must adopt a Climate Action Framework (as discussed in Chapter 5) and find local and feasible climate change solutions to achieve low carbon goals. PMR should play the pioneering role of deep decarbonisation for Indian cities by adopting this framework.

2.1. Rapid Urbanization Challenges

Urban centres with opportunities and jobs are attracting a vast population from surrounding peri-urban or rural areas world over. Nearly 85% of this rapid urbanisation is happening in developing countries, India is a classic example. Coordinated and collective action by the cities of the world – where 70% of the planet's population may reside by 2050 - is critical to containing global warming to within 1.5º C which is

now accepted as the limit to save small Island nations and coastal cities of the world. For India, the percentage of population in urban areas was 31.16% in 2011 census but is expected to rise to over 40% by 2030 amounting to about 600 million population – a very large chunk of humanity.

Cities cover less than 2% of the earth's surface area and yet account for about 75% of the global CO_2 emissions due to extensive industrialisation and energy use and are also the largest generators of garbage. Cities are not only the largest contributors to the global climate change problem, but many of them may also become early victims of the phenomenon.[Ref 7] Almost 90% of the global urban areas, each with a population of more than 10 million are coastal and are under immediate threat because of the expected sea level rise. 70% of them are already dealing with climate change impacts.

19 city governments – Copenhagen, Johannesburg, London, Los Angeles, Montreal, New York City, Newburyport, Paris, Portland, San Francisco, San Jose, Santa Monica, Stockholm, Sydney, Tokyo, Toronto, Tshwane, Vancouver and Washington DC have committed to largely cut GHG emissions by ensuring new buildings will operate at net zero emissions by 2030, and all old or new buildings will meet net-zero carbon standards by 2050. Milan, Italy will have a zero-emission historical city centre by 2030, with fossil fuel vehicles banned from city centre by 2029.

The City of Miami, US is already getting flooded during high tides and property values are tumbling fast in this famous resort town. New York City recently released a plan setting out how the entire city aims to be carbon neutral by 2050. In India, the metro cities like Mumbai, Chennai, Kolkata would be the ones to get affected first with sea-level rise. This would compound the challenges for such rapidly urbanizing cities. However, with their high density of population, economic activities and infrastructure, cities are the most scalable opportunity for climate action.

A rapid rise in urbanization leads to complex issues like slums, the decreased standard of living, pollution, socio-economic stress, degradation of resources and environmental damage. Cities are rapidly expanding and experiencing radical social and economic transformations across the world.By 2030, urban centres in India will generate nearly 70 percent of the country's GDP.[Ref 8][Ref 9] Climate change may have major health impacts in India and increase malnutrition and related health disorders such as child stunting (to 35% by 2050). Increase in temperatures will lead to an increase in the frequency of Malaria and other vector-bornediseases in colder regions which were earlier protected by low temperatures.

[Ref 7] C40 Website (https://www.c40.org/why_cities)

Increasingly severe and frequent heat waves may substantially increase mortality and death incidences. diseases in colder regions which were earlier protected by low temperatures. Increasingly severe and frequent heat waves may substantially increase mortality and death incidences. The damage and health hazards caused by all extreme weather events are likely to drastically increase.

PMR has become one of the fastest-growing cities in India. With a booming population of 7 million residents that is increasing at a yearly growth rate of 2.25 %. This is primarily due to the high migrant influx from the rural as well as urban parts of India for job opportunities. Therefore, as the region further urbanizes, the demand for electricity is also going to increase with it. It's safe to assume that the amount of CO_2 emitted within PMR is set to double by 2030.

With the growth of industries and economic opportunities, the migration in all cities around is increasing in number. And so, are the challenges associated with compounded by Climate Change Mitigation and Adaptation imperatives. Carbon Neutral Cities will be the most successful cities in the world and PMR should lead by example to place India predominantly on the global map.

2.2. Green Development Priorities

India needs to spend about $134 per capita to support urbanization capital expenditure (Capex). But the used expenditure of $20 per capita, population growth and rapid urbanization are combining to create huge challenges for all Indian Tier II and III cities.[Ref 10] Additionally, lack of government planning leads to unsustainable land use like urban sprawls, illegal slums and hawker zones. Without appropriate planning, design and management this massive urban growth would worsen the existing health, environment and security issues.

According to the PMRDA Website, current PMR population is 72,76,000. Factoring the slightly reducing growth rate per year, we estimate that it will reach 95,02,054 i.e. or nearly 10 million by 2030. Which implies 31% population rise in just 10 years. Thus, Satellite townships and Peri-urban regions will play a key role in achieving carbon neutrality in expanding urban centres like PMR. Green townships provide affordable basic facilities like housing, healthcare, education and public spaces to ensure the economic growth of region without compromising environment.

[Ref8] S. Sankhe, et al (2010), India's urban awakening: Building inclusive cities, sustaining economic growth, McKinsey Global Institute.
[Ref9] A. Roy (2009), Why India cannot plan its cities: informality, insurgence and the idiom of urbanization. Planning Theory, 8(1), 76–87.
[Ref10] S. Sankhe, et al (2010), India's urban awakening: Building inclusive cities, sustaining economic growth, McKinsey Global Institute.

The peri-urban region in PMRDA will have diverse economic activities, and any attempt to classify it into solely urban or rural strategies or development plan will not be successful. Hence, planning in these rapidly developing areas must be strategic rather than comprehensive and take into consideration the local environment as well as the social, economic and cultural characteristics.

Green development goals for PMR should include ambitious time-frames for climate change mitigation & adaptation outcomes, effective monitoring & implementation along with participatory governance. They should also provide normative entitlements to all citizens and conduct public meetings and multiple stakeholder interactions for developing the PMR master plan and executing it.

Change in 'Land Use' contributes to 12.5% of the total GHG emissions worldwide.[(Ref 11)] PMR region includes many carbon sinks and some parts of the biodiversity-rich Western Ghats. Thus, the region must be thoroughly mapped using the field as well as GIS techniques to build sustainable infrastructure. It is crucial to carry out feasibility studies and Environmental Impact Assessment of the entire region, followed by a systematic and strictly implemented Development Plan for PMR before it is too late to capitalize on this avenue. It is known that reduced quality of life negatively impacts economic growth.

2.3. Role of Technology & Innovation

There is a constant search for advances in technologies for expanding the options for renewable energy (RE) sources, so that future generations may have access to abundant clean energy essential for staying on course with development objectives without compromising the environment. Renewable Energy (RE) such as Solar, Wind and Biogas have not only become competitive with thermal sources, but they are also well suited for distributed generation for off-grid local solutions. There are also innovative approaches evolving for removal of carbon dioxide from the atmosphere at a scale that could provide opportunities for net-carbon neutrality even for high energy-consuming societies. All these represent the 'Next-Gen' technology promises for the future.

2.3.1. Carbon Capture and Storage (CCS)

Carbon dioxide capture and storage (CCS) is the technology used mainly for preventing emissions at the point of generation itself, which would otherwise be emitted in the atmosphere. CCS efforts also focus on the removal of carbon dioxide directly from industrial or utility plants and subsequently storing it in secure geological reservoirs.

[(Ref 11)] R. A. Houghton et al (2012), Carbon emissions from land use and land-cover change, Biogeosciences, 9: 5125–5142.

The rationale for CCS is to enable the use of fossil fuels while reducing CO_2 emissions into the atmosphere and thereby mitigating global warming and climate change to some extent. CO_2 capture processes in power production have three general categories: 1) post-combustion capture, 2) oxy-combustion capture, and 3) pre-combustion capture. The first two categories are compatible with the existing pulverized coal power plants that rely on the combustion of fossil fuels. The last is generally reserved for incorporation into an integrated gasification combined-cycle (IGCC) power plant.

There are also 'Negative Emission Technologies' emerging that could be crucial to reach “net zero” carbon emissions – the point where any climate pollution we add to the atmosphere is balanced by what we take out. A key challenge is getting to the scale required. It is estimated that to meet its climate targets, the world will need to remove as much as 10 G-Ton of CO_2 from the atmosphere each year by mid-century – nearly twice the current annual emissions in the U.S. alone. Pricing carbon emissions through a carbon tax or an emissions trading system can also create an economic incentive for cheaper, faster ways to cut pollution. Many such solutions are evolving. For future generations of human civilization who will have to face a more hostile environment, technology and innovations will have to provide new solutions for problems that are not even visible today.

GREEN TOWNSHIPS

Green Townships must incorporate climate change adaptation and mitigation in planning using the following mandates.

- ***Self-sufficient settlements supporting basic requirements of 75,000 - 1,00,000 people***
- ***Energy-efficient planning to reduce energy demand and losses***
- ***Maximum electricity independence by distributed generation with RE***
- ***Rainwater harvesting in recharge zones; recycling and reuse of water***
- ***Sewage Treatment at source using low carbon technologies***
- ***Suitably treated wastewater used to irrigate and/or fertilize nearby fars***
- ***Educational and vocational training centres including soft-skills centres***
- ***Easy access to internet and green technologies***
- ***Transit-oriented transport to encourage walking, cycling and public transport***
- ***Not disturbing native ecosystems and environmental water flows***
- ***Developing open and recreational spaces and greening campuses***
- ***Diligent monitoring and assessment of change in land use, risk factors, resource use and quality of environmental assets and strict action against non-conformance.***

2.3.2. Innovations in Energy Sector

Solar energy is the most promising technology today and there are many promising incremental innovations like the Perovskite solar cells that could operate at 28% efficiency and provide flexible solar panels for wider applications. It is about to enter the market later in 2019. 'TESLA Wall' energy system with solar roof-tiles and wall-mounted advanced battery storage systems are already selling fast in California homes for 24x7 high-quality solar power in stand-alone mode. Other innovations include foldable solar-trees that are portable and provide higher output per-square-meter foot-print. The city of Istanbul is testing hybrid vertical Solar-Wind mini-towers on highway median strips that use wind from fast-moving traffic.[(Ref12)]

With the fast pace of battery storage technology, distributed power generation opens up a new horizon for 100% efficient utilization of clean power at remote locations. Such solutions will also be important for charging E-Vehicles which otherwise will have to charge the batteries from grid power, thus, increase the grid-load and the consequent emissions. Hydrogen is another futuristic option for producing abundant clean energy and hydrogen-powered cars are already being used in advanced states like California. Generation and storage of hydrogen is still not cost-competitive and as user base increases, may become affordable, particularly in Auto-industry.

Nuclear energy is a proven clean energy option, but in India it is not popular due to its perception as environmentally hazardous and even life-threatening in the event of an accident. The technology has made significant progress and developed the Generation IV nuclear reactors are much safer. The closed loop fast-breeder reactors, tested in India offer attractive benefits such as less radioactive waste and far safer operations. But India is yet to leverage this option for lack of political will. Given the more adverse impacts of climate change soon, this technology option deserves a serious re-look for an India specific solution. These are indeed options that cannot be available for a local government to deploy, but spreading correct awareness can always help decision making at the State or National level.

Other benefits of technological innovations for 'Net-Zero' emission solutions include artificial sequestration or direct removal of GHG gases from the atmosphere. Scientists have designed synthetic trees that can trap carbon dioxide from the air in an attempt to combat growing emissions. The device can collect carbon about 1,000 times faster than a natural full-grown tree. One synthetic tree can absorb one ton of carbon dioxide per day and this can be trapped in a chamber so that the carbon can be compressed and stored in liquid form for sequestration. Artificial trees are made from a special resin – a unique plastic that sponges up CO_2 from the air in a chemical reaction. When the resin is dry, it has an exceedingly high affinity to carbon dioxide. And when the resin is submerged in water, it releases the carbon dioxide.

[(Ref12)] R. Thresher, M. Robinson, P. Veers, NREL, (2008), Wind Energy Status: Current Status and R&D future

2.3.3. Environmental Engineering

Lack of progress towards decarbonization of world energy systems has created justifiable panic about the climate crisis. This has led to an intensified interest in technological climate interventions that involve increasing the reflection of sunlight to space by injecting substances into the stratosphere which lead to the formation of highly reflective particles. When first suggested, such albedo modification schemes were introduced as a 'Plan B,' in case the world economy fails to decarbonize. But because of the mismatch between the millennial persistence time of carbon dioxide and the sub-decadal persistence of stratospheric particles, albedo modification can never safely play more than a very minor role in the portfolio of solutions. There is simply no substitute for decarbonisation, says Raymond Pierrehumbert in his article 'There is no Plan B for dealing with the climate crisis'.

Yet another method for removing excess carbon dioxide from the atmosphere could be: converting biomass into a long-lived, charcoal-like material that would be added to the soil. Called 'Biochar' this material could not only sequester some of the carbon fixed by plants during photosynthesis – and prevent it from returning to the atmosphere – but it could also improve soil fertility. There are some trade-offs and uncertainties associated with biochar and other methods of soil carbon sequestration, and the challenges to scale up these approaches for global climate change mitigation, are yet to be addressed in an economically competitive manner as mentioned in an interview by Dominic Woolf, Cornell University.

2.4. India's International Commitments

Historically, the more affluent developed countries have been largely responsible for the global problem because of their high per-capita energy consumption. Only 20% of GHG emission could be attributed to poor developing countries that hold 80% of the global population. But global warming effects do not recognize country boundaries and Climate Change impacts will be common for most with very small variation dependent only on geographical parameters.

Therefore, developing countries have been arguing for differential responsibility and asking for financial and technical assistance in dealing with climate change. However, with China and India making strong economic progress in the last few decades, they can no longer claim for benefits to poorer countries. They stand alone on the international platform as regards climate change negotiations. India has been an active member of the International focus on Climate Change debate since the Rio conference (1991) and shaping its national policies concerning ground realities. India understands its high vulnerability to climate change due to its geography, population, inadequate infrastructure and finances to deal with major disruptive events.

India is highly dependent on the Monsoon for economy, and increase in uncertainty of weather systems will further increase vulnerability. Being a tropical country, it will be severely affected at many levels through unpredictable weather events like flash flooding, frequent long droughts, rise in sea level and shortage of potable water. With frequent heat waves and steady loss of ecosystems, India is recognized as one of the most vulnerable countries to Climate Change in the World.

Majority of the Indian population still lives in rural areas that directly depend on climate-sensitive sectors like agriculture, forests, and fisheries. These sectors are heavily dependent on natural resources such as water, biodiversity, mangroves, coastal zones, and grasslands. With increasing intensity and frequency of climatic disasters and changing weather patterns, Indian cities will face considerable stress. Climate Change will also have adverse impacts on food production, water supply, biodiversity, livelihoods and national security, affecting efficiency of Defence forces.

The Indian Prime Minister, at the Paris Climate Conference in Dec 2015 has put forth some of the most ambitious climate targets as Nationally Determined Commitments (NDC) for 2030. India committed to reduce the emissions intensity of its GDP by 33–35% below the 2005 level by 2030. And also achieve 40% of the total installed electric power capacity from 'non-fossil fuel energy' sources like solar, wind and biomass by 2030. And another important commitment to create an additional carbon sink of 3 billion tonnes of CO_2 sequestration capacity (compared to 1 Billion tonnes in 2015) through additional forest and tree cover by 2030. All State Governments have to be very proactive to achieve these challenging commitments and goals.

India has recently revised its RE (Renewable Energy) generation capacity building to 175 GW by 2022 from the already ambitious target of 100 GW capacity. Such promising initiatives driven by Central Government open up the opportunity to aim for near 100% energy from indigenously produced RE sources to drastically and rapidly reduce the dependence on Coal and Gas to cut-down CO_2 emissions. To strengthen such ambitious goals, Government of India has also announced a policy decision to shift to Electric Mobility beginning 2020 and achieve a near-total shift to e-mobility with RE charging facility across the country by 2030 to eliminate the dependence on imported oil. These are very important goals to not only make India honour its climate change responsibilities but also go beyond the NDC commitments for achieving carbon neutrality by 2050. This will also enable its economy to grow without any penalty to the environment.

India aims to adopt a more climate-friendly and cleaner path to achieve economic development than any country in the past. It needs to simultaneously balance – expanding electricity access and achieving its climate target. India needs to drastically reduce GHG emissions by reducing Carbon Footprint at individual, community and organizational level and by implementing better Climate Change Mitigation and Adaptation Policies.

India's energy system faces the triple challenge of meeting growing demand, cutting pollution and offering access to electricity to people not yet connected to grid power. India's power demand is projected to increase three-fold from 2015 to 2040.[(Ref13)]

Shifting away from coal-power to less-polluting options must get priority. India is determined to achieve 40% cumulative electricity generation capacity from non-fossil-fuel based energy resources by 2030. Current Electricity Demand is 14,000 GWh and is expected to rise to 25,000 GWh by 2030. A major chunk of this demand will arise from rapidly urbanizing centres, and hence, regions like PMR must create suitable infrastructure for enabling the rapid shift to RE.

There is growing awareness that even if all countries meet their Paris commitments that may not be enough to stay within 2°C warming to avert serious climate impacts. Hence all countries, particularly those most vulnerable to climate change, must go beyond Paris commitments. India aims to achieve its Nationally Determined Contributions (NDCs) and go beyond because these targets are economically wise, and India can benefit from its strong institutional framework and robust domestic policies to get reliable financing to achieve the NDC objectives and go beyond.

[(Ref13)] R. Tongia, S. Harish, R. Walawalkar (2019), Brookings India Integrating Renewable Energy in India's grid – Harder than it looks.

Chapter 3

Energy Solutions for PMR 2030

Chapter 3. Energy Solutions for PMR 2030

Like most growing cities in India, PMR's massive demand for energy came at a heavy environmental cost. Last year, more than 14 million tons of CO_2 (MT-CO_2eq) had been released unchecked within PMR as a consequence of energy consumption. Such emissions account for more than 70% of PMR's total emissions every year.[Ref14] As a result, an urgent need to adopt ambitious targets and measures within the energy sector becomes vital to drastically reduce the carbon emissions. This chapter on 'Energy Solutions' highlights the pathway to enable such an energy transition and further delineates the major advantages of the technological shift that can enable a sharp reduction in carbon emissions.

Clean renewable energy (RE) sources must be harnessed at all levels within PMR jurisdiction. Such a transition has the capacity to significantly reduce the region's dependency on coal based grid electricity. PMRDA must also rapidly develop RE infrastructure such as micro-grids using batteries as well as distributed solar generation throughout the region. At the same time, adoption of wind power or biogas generation must also simultaneously take place to ensure a holistic energy basket. If PMR achieves RE energy abundance, e-vehicle should be charged through RE, independent of thermal powered grids that would otherwise continue polluting CO_2 emissions.

Adopting RE also has its own economic benefits due to the competitive cost advantage over coal power (which despite subsidies can no longer compete with solar or wind power).[Ref15] Due to the present innovative system of competitive bidding in India, cost of solar power generation has come down to Rs 2.44 Crore/MW allowing consumer tariff at about Rs 3.5 to 4 per KW-hour (Unit) without any subsidy. Wind power scenario is also very similar, except it requires more time for installation.

Thermal power plants in India are further strained by coal supply shortages and increasing costs due to imported oil price fluctuations. With likely addition of carbon tax in the future, the gap between RE and Coal-power will further increase making thermal power economically non-viable.

The writing is on the wall where trends show that investments in the energy sector increasing to 74% of new power capacity additions in 2018.[Ref16]

[Ref14] N. Mate (2019), Baseline Carbon Emissions Assessment of Pune Metropolitan Region For The EECC Project of Pune International Centre
[Ref 15] The Hindu Businessline Website https://www.thehindubusinessline.com/economy/indias-renewable-energy-cost-lowest-in-asia-pacific-woodmac/article28744167.ece
[Ref16] Clean Technica Website: https://cleantechnica.com/2019/01/21/74-of-indias-new-power-capacity-addition-in-2018-was-renewables/

3.1. Rapid Shift to Clean Renewable Energy (RE)

Last year PMR emitted 10 million tons (MT) of CO_2 from electricity generation and 4 million tons (MT) of CO_2 from fuel burnt for transportation. A continuation of these trends would lead to tripling of CO_2 emissions in the coming decade. PMR however can achieve net carbon neutrality and drastically reduce carbon emissions from energy consumption by adopting RE technologies that utilize solar, wind and biomass resources to generate electricity. Each source plays a critical role in reducing the carbon emission and respective technology with its economic viability has been separately explained here.

3.1.1. Solar

India is blessed with abundant solar radiation with an average of 300 sunny days per year. However, solar energy had not been popular in the past due to low efficiency of conversion and high cost. In the late 90s, solar water heating made immense progress and roof-top heating panels for water heating have now become a fairly common sight in India.

Today with the support of available government subsidy and the need to reduce household electricity consumption, the technology of Solar Photo-Voltaic (SPV) for direct conversion to electricity has been making impressive progress in the past decade with dramatic reductions in costs.

Significant improvements in SPV has led to an efficiency of over 15% at panel level for the end user. With an increase in the supply of technology innovations, today the cost of commercially available solar panels has remarkably reduced to about Rs 50,000 per KW with 25-year performance warranty. Today 10 square meter of solar panel system can provide 4 to 5 units (KWh) of electricity for every sunny day.[(Ref 17)] This averages to 150 units per month allowing cost saving of over Rs 1800 x 6 = Rs 10,800 for 300 days a year (assuming 6 Rs/unit average tariff of thermal power). The actual cost comparison is far more in favour of solar because there is no recurring cost of energy and no polluting emissions added to the atmosphere.

The innovations in SPV technology is now advancing solar PV efficiency to over 25% from new generation "Perovskite" solar cells that's expected to enter the market in 2020. The future of solar is witnessing a wave of transformation where solar power is be able to supply abundant energy with a modest area coverage at very competitive cost. Such new panels will be far more versatile and physically flexible for wide applicability at low cost. Similarly, even concentrated solar technology is becoming incredibly efficient and cost-effective to build. Such technologies with innovations in battery storage technology as well as other new technologies such as molten salt storage etc. have created the capacity for abundant indigenous solar power generation in near future.

[(Ref 17)] Energy Sage Website https://news.energysage.com/solar-panel-efficiency-cost-over-time/

This is a new era of clean non-polluting electric power that can help mitigate climate change.

The future of solar power looks very promising with steady drop in cost of supporting equipment like smart charge controllers and DC-AC inverters. With battery technology advances, compact solar power back-up units can soon replace diesel gen-sets for better convenience and major cost advantage. This will be discussed further.

3.1.2. Wind

India's well-developed wind power industry has the capability and experience to help meet the country's climate and energy security goals. Today India is the 4th largest wind market globally and is on-track to meet the short-term national target of 60GW by 2022. With wind power technology evolving fast, the industry is also involved in bringing new products to market that meet the needs of the local conditions within the country. Wind, unlike solar, is not ubiquitously abundant across India. However, technology for wind power has also quickly progressed to further explore different avenues to overcome topographical limitations.

The Vertical Axis Wind Turbine (VAWT) is one such technology that, when placed on highways or train tracks, capitalizes on the winds induced from passing vehicles to generate electricity. Combined with solar panels on top such compact tower units have immense potential within urban areas with even moderate density of traffic (Figure 2). Hybrid wind-solar distributed system often complement each other for extended power generation – ideal for a city like PMR to establish RE Micro-grids.

Figure 2: Vertical Axis Wind Turbine (VAWT)

In the medium term, digitally connected sensors and AI-driven software are being incorporated into smart turbines that can anticipate and react to changing conditions, predict component longevity, and communicate with remote data centres or the grid to increasingly automate O&M operations.

All of the choices would lead to boosting productivity and saving costs.[Ref18]

3.1.3. Biogas

Since the 1970s, India has been one of the largest household biogas users in the world. Today with technological improvements, biomass has evolved its capacity to generate usable gas using a variety of resources, from manure to a variety of organic waste, which can support cooking as well as industrial heating applications in urban areas. Today bio-fuels like methane produced from biogas have been found to be a direct fuel replacement to CNG. It is also used as a direct replacement for LPG cylinders as well.

Biogas plants have increasingly become relevant in generating electricity and in producing manure both in urban as well as rural areas. A good example in Pune is the Model Colony Biogas Plant situated at near central Pune which is one of the several functioning biogas plants across the city. Last year, the plant locally collected more than 10,000 tons of wet waste to generate 1.2 Lakh KWh of electricity and 700 tons of manure.[Ref 19] PMR with large patches of peri-urban areas can plan for efficient of rural waste for useful conversion of waste into energy.

3.2. Distributed Generation with Storage Technology

Today the centralized grid system based on fossil-fuel power plants is largely responsible forever 40% of CO_2 emissions. Its high T&D losses are also a major loss. Now the imperative to cut down the carbon emissions from electricity can be achieved with distributed generation of clean Renewable Energy (RE) where it is required with zero losses. This enables individuals, small communities or industries to generate their own clean electricity power. [Ref 20] From a financial perspective, it also reduces the overall capital investment required for creating additional generation capacity. The cost per KWh for using solar energy even with battery storage today is less than Rs12 /KWh as compared to over Rs 20 per KWh of a diesel gen-set for back-up power. While intermittency of supply is probably the only drawback of solar or wind energy, advances in battery storage technologies like the 'Tesla-Wall' home storage systems, are attractive solutions to provide clean uninterrupted electricity round the clock. Li-ion batteries are becoming increasingly popular since 2017 because they are highly energy efficient, maintenance-free, have long lifetimes and competitive cost. They are also very compact and can be mounted to walls allowing space savings.Between 2013 and 2018, the average retail price for lithium-ion batteries fell by more than 50%.

[Ref18] DNV- GL Annual Report
[Ref 19] G. Pandit, S. Jagtap (2018), Model Colony Solid Waste Treatment –A case study, International Research Journal of Engineering and Technology (IRJET).
[Ref 20] A. Oberhofer, (2012), GENI, Energy Storage Technologies & Their Role in Renewable Integration

(PV Tech, Vol 20) Distributed systems can also be connected to the central grid via net-metering to allow the consumer to trade daytime solar generation with night-time use of grid electricity. This helps in lowering the grid electricity bills while also lightening the load on Distribution Companies (DISCOMs).

ROOFTOP SOLAR PV WITH STORAGE: REAL SOLUTION FOR CITIES

The declining cost of lithium-ion batteries and solar is likely to change the future dynamics of the Indian power sector. Several countries such as Australia, the US and Germany have already endorsed solar power with battery storage.The viability of storing solar power using batteries and using it during peak times is increasing due to declining battery prices. At present in India, commercial and industrial consumers face steep electricity costs, as well as frequent disruptions in the power supply. Installing a solar plus storage system can address both these issues and significantly reduce electricity bills and is thus a win-win solution.

For consumers, the benefits are: Reliable and affordable power; Ready backup power; manageable demand using storage system and reduced demand charges; Saving cost of alternate energy from diesel gensets : A recent ban on diesel gensets in certain parts of India (Delhi/ NCR) has created the need for new energy sources and It is also an environmentally friendly option. For DISCOMS, it helps in reduction of transmission and distribution losses and saves on the investments in transmission and distribution infrastructure. At present, a 1 MW rooftop/ onsite solar plant with 250 kW of battery storage (4 hr backup), is already a viable solution for commercial consumers across key states in India. For industrial consumers, solar with storage is feasible in seven key states except, Tamil Nadu, Andhra Pradesh, and Telangana.

(Courtesy JMK Research Analytics)

3.3. Transition to E-Mobility with RE Charging

The transport sector is a key enabler for economic activity and social connectivity. Given the ever-increasing demand for mobility, this sector is also continuously adding to its cumulative CO_2 emissions.[(Ref21)] According to the EPA, 24% of total global emissions come from the transportation sector, which is almost one fourth of the total carbon emissions. To drastically reduce the emissions from this sector, a rapid shift to e-mobility becomes an imperative. While efforts such as increasing the use of public transport systems and enforcement of stringent vehicular emission standards for reducing emissions are taking place, there is now recognition that such incremental measures would be woefully insufficient to transform the sector to low-carbon levels required for combating climate change. The governments of most pragmatic countries have already recognized the shift to electric vehicles as the most promising solution.

[(Ref21)] R. Sims, et al (2014), Transport in Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

The government of India is also aggressively pushing for the transition towards e-vehicle while the NITI-Aayog (Govt. Think Tank) is seeking to ban all internal combustion engines by 2025. The central government has recently released the FAME 2 scheme (Faster Adoption and Manufacturing of Hybrid and Electric Vehicles) for e-vehicles with an investment of 10,000 crores.[(Ref22)]

However, along with the shift to e-mobility, public and private institutions must also simultaneously invest in RE based battery charging infrastructure to avoid the use grid-power that may remain dominantly dependent on coal-based. Loading all the additional vehicle charging power requirements to the grid will defeat the purpose of reducing carbon emissions of the transport sector as the benefits of EV specifically for reducing carbon footprint would be negligible. Hence all vehicle charging infrastructure independent of thermal grid supply must be created in PMR. All charging stations must provide electricity only through Solar with battery storage for 24x7 usability to make a real difference. PMR is estimated to have more than 9 million vehicles on its streets, emitting an average of 6 million TCO_2 every year. In a business-as-usual (BAU) scenario an average of 3 lakh vehicles will be added in PMR every year which further increases the annual emissions every year.

With EVs investment growing every year, there is an urgent need to adopt targeted policies to significantly reduce CO_2 from fuel-use for transportation. Some recommendations for PMR to set up EV infrastructure in the city are –

- Website to inform & encourage electric vehicles with citywide EV plans and consistent outreach to promote EVs in PMR will be essential
- Installing EV charging stations in commercial parking places including every public and private parking must be mandatory building completion
- Municipal requirement in building code that requires parking garage owners to allow tenants to install EV charging stations if they want to
- Public transportation freight should be moved to e-mobility on priority and should provide RE charging in their depots.
- RTO should play a role in monitoring a database on e-vehicle usage and disposal (including battery disposal)
- Exemption/reduction on local taxes for EV ownership, including road tax, registration tax, etc. as incentives
- Direct subsidies for EV purchase or lease from local municipality or utility
- Free parking for EVs at city centre or in other select sectors of the city with RE charging facilities.
- Exemption from local use fees and tolls for EV owners
- A battery swapping scheme particularly for e-vehicle fleets of govt. private companies or schools etc. across PMR can be very effective.

[(Ref22)] Livemint Website https://www.livemint.com/auto-news/meet-ev-deadline-or-pay-up-for-pollution-centre-may-tell-auto-manufacturers-1564599913908.html

3.4. Energy Transition for Low Carbon Economy

As already noted earlier, urban areas cover less than 2% of the earth's surface area and yet account for about 70% of the global CO_2 emissions (considering final energy use). Cities are also more vulnerable to climate change impacts. Almost 90% of the global urban areas, each with a population of more than 10 million are under immediate environmental instability threat and 70% of them are already dealing with the effects of climate change.[Ref23]

This is why mitigating the effects of climate change at urban levels must be urgently prioritized. Last year PMR's CO_2 emissions through energy and fuel consumption was more than 16 million tons of CO_2 (per year). Since these emissions also account for more than 60% of the total CO_2 emissions emitted from PMR, it is critical to immediately begin transition to clean energy and make PMR an energy efficient urban centre within its own jurisdiction producing its own indigenous energy.

Fortunately, PMR is uniquely positioned to push for such an ambitious transition, because unlike cities like Mumbai and Delhi, majority of PMR area is peri-urban and yet to be developed. In fact, PMR needs to utilize just 6% of its total land capacity to generate enough Solar electricity to run itself for an entire year. Suitable land for such solar farms can also found outside the PMR area for electricity generation.

Similarly, in the next ten years, future constructions within PMR will also eventually become the majority of the residential and commercial buildings in the region. If PMR takes action by proactively ensuring strict compliance to ECBC codes for all new constructions, it can significantly increase the energy efficiency and reduce its overall energy demand across the region (*Refer section 4.1.*).

PMR could eventually become the first urban centre in India to pioneer a low carbon economy. Such an endeavor would not only increase private investments in the city but also generate thousands of new jobs. In fact, the first annual jobs census by industry body 'Power for All' forecasted that more than 400,000 jobs would be created in India by 2023 in the renewable energy sector.[Ref24]

Through the transition, PMR must also transfer its own strategies and learnings for other cities to replicate. What needs to be seen in the next 20-30 years is net carbon neutrality achieved in every city. In fact, PMR must go further, with the use of carbon capture technology to become net carbon negative so as to offset the emissions of other cities which need more time to become carbon neutral. It's only through such an imperative that we will be able to protect the future generations from witnessing a climate crisis.

[Ref23] World Bank, Cities and climate, an urgent agenda. December 2010, Vol. 10.

[Ref 24] Economic Times Website https://energy.economictimes.indiatimes.com/news/renewable/jobs-distributed-renewable-energy-sector-to- create-400000-jobs-in-india/70224080

Chapter 4

Achieving Carbon Neutrality for PMR

Chapter 4. Achieving Carbon Neutrality for PMR

Carbon footprint is the total amount of greenhouse gases (expressed in equivalent metric tons of Carbon Dioxide i.e. TCO_2eq) which are emitted directly or indirectly as a result of human activities by individuals, organizations or regions. It is necessary to rapidly reduce 'Carbon Footprint' of the city at every level to become Net Carbon Neutral.

CO_2eq emissions are divided into three types. Scope 1 (direct emissions) and Scope 2 (indirect emissions from electricity) emissions are relatively easier to estimate. Quantifying Scope 3 (other indirect emissions) from cement, steel, waste, fertilizers, etc. is challenging. Analysing and understanding the distribution of emissions within these scopes is important to determine the plan of action to reduce them. Multiple actions need to be carried on various fronts as given in the following sections.

Table 2: Scope 1, 2 and 3 emissions in PMR

PMR Emissions	Co_2eq Emissions (TCO_2/Year)	Percentage
Scope 1	67,83,870	26.03%
Scope 2	1,08,73,200	41.72%
Scope 3	84,04,227	32.25%
Total	2,60,61,297	100.00%

Scope 1 and Scope 2 emissions were estimated using direct fossil fuel consumption and using CEA emission factor for consumption data shared by MSEDCL Pune Office respectively. Scope 3 emissions calculations were limited due to non-availability of reliable data. But some Scope 3 emissions were accounted for using the emission factors standardized for automotive, building and fertilizer industries.

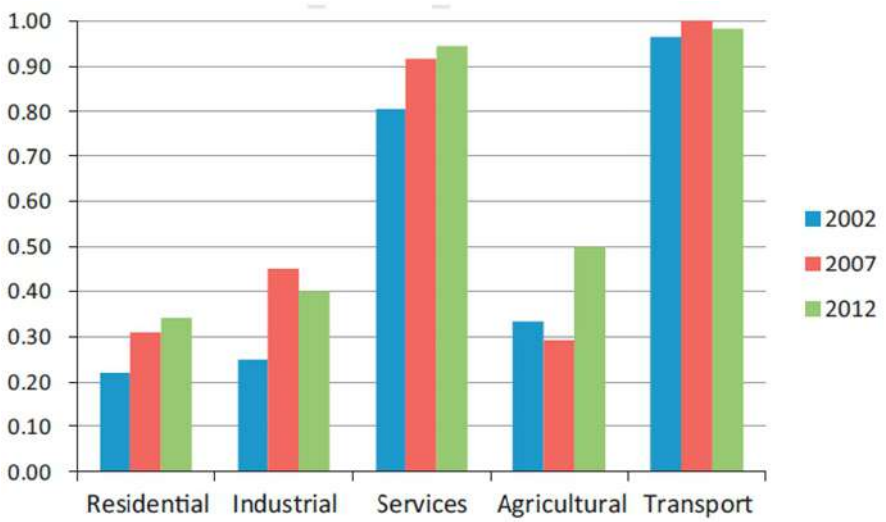
4.1. Improving Energy Efficiency to Reduce Demand

India remains one of the few countries with rapidly growing power demand, and its total electricity consumption is projected to increase about threefold between 2015 and 2040. A major chunk of this demand will arise from rapid urbanization. If unregulated, it will create huge pressures on all municipal services and citizens. The electricity sector already contributes to 40-50% domestic GHG emissions.

Energy efficiency and reduction in energy demand will play a significant role along with adoption of clean energy alternatives (*Refer Chapter 3*). As India continuously pushes to meet its electricity demand, these measures will avoid energy wastage, losses and will allow a smoother energy transition to take place. Hence, they are an inseparable part of Climate Action. Demand reduction will also likely make energy distribution more equitable and improve efficiency of supply.

Energy efficiency is essential for sustainability as it not only saves money, but also prevents reduces the load on the environment. Today India's energy efficiency across sectors is very low. Since PMR will have energy usage in all the following sectors, improved efficiency is crucial for financial gains and true energy independence.[(Ref25)]

Figure 3: Sector-wise Energy Efficiency in India



End-user efficiency can be improved by awareness about reducing demand, continuous electricity supply, using more efficient devices requiring less wattage and smart metering options. In transition to e-vehicles, the energy efficiency of the vehicle is critical to actually reduce emissions as compared to fossil-fuel powered vehicles (*more in section 3.3*). Installation of LED streetlights alone has reduced the national annual GHG emissions by 1.39 million tons.[(Ref26)]

Improved urban planning reduces a city's dependence on imported fuels and reduce energy costs. This helps in freeing up resources for improved city services and socio-economic benefits. India needs to rapidly reduce its emissions intensity for sustainable energy use. PMR, still in the planning phase, has a huge potential to achieve this by using models like the 'Energy Efficient City Initiative'.

(Ref25) S. Dhaka et al (2012), Combined effect of energy efficiency measures and thermal adaptation on air conditioned building in warm climatic conditions of India, IIIT, Hyderabad.

(Ref26) S. Kumar (2019), For clean air, focus on energy efficiency, https://www.thehindubusinessline.com/opinion/for-clean-air-focus-on-energy- efficiency/article27472850.ece

Cities require locally customized approaches for developing sustainable energy strategies, monitoring and implanting them, and finances for evaluating investment options. In the case of PMR, this can be achieved by following actions.

4.1.1. ***Diagnose Inefficient Energy Use and Offer Solutions*** – Develop tools to review existing systems for performance; identify sectors where the most improvements can be made and provide a list of policy recommendations, actions, and investment options to save energy and lower costs. Energy monitoring in Municipal facilities like street-lighting, waste, water and sanitation utilities.

4.1.2. ***Share Good Practices and Reward Innovation*** – Establish an online database to share good practices from all city sectors, Promote targeted publications on global good practices in public procurement, building codes, sustainable transport, and other areas.

4.1.3. ***Improve Energy Distribution*** – Make distribution more equitable and improve supply quality to reduce the use of inefficient alternatives. For this, improve end-use efficiency by using modelling, optimization, suitable technologies and methods to reduce demand.

4.1.4. ***Adapt Energy Efficient and reject Energy*** – intensive Appliances and Processes – All electricity-powered devices should have energy ratings. Only the efficient devices requiring less wattage and having good Bureau for Energy Efficiency (BEE), GOI ratings should be used at all levels. It is also necessary to set minimum standards; below which, any appliance or process will not be permitted to be commercially sold. Simultaneously, Phasing out sales of energy-intensive appliances like Diesel Gen-Sets & incandescent lamps with supply-side incentives will help to reduce CO_2eq emissions.

4.1.5. ***Technology and data science for optimization*** – Efficiency and knowledge in Energy planning, generation, distribution, supply and use is a critical aspect for achieving carbon neutrality. If PMR is to keep up with the technological revolution and achieve its goal of carbon neutrality, Artificial Intelligence (AI) and data science needs to be incorporated in the process of achieving energy efficiency.

AI and data science can be used to optimize transmission, distribution and supply. By installing Smart-Metering for real-time estimates of daily usage and peak times, better load distribution, data collection, billing, and monitoring can be ensured. Sensors, planned interior lighting, Video-conferencing minimize travel. Robotics and Artificial Intelligence can revolutionize the energy demands of future societies, if planned properly with energy conservation as the ultimate aspiration.

Thus, reduction in energy demand and increasing Energy Efficiency in all sectors and all planning and at all levels including individual, community, institutional and governance needs to become common practice.

Its advantages are already known, however, now the cost of not achieving it is also becoming more apparent due to stress on resources. Only sustainable energy use can ensure rise in opportunities in PMR without incurring risks and losses associated with inefficiency and over-use.

Extending the lifetime of all washing machines, notebooks, vacuum cleaners and smartphones in the EU by just one year would save around 4 Mt CO_2eq annually by 2030, the equivalent of taking over 2 million cars off the roads.

4.2. Major Sectors for Reducing Carbon Footprint

Urban activities that are major contributors to greenhouse gas emissions are infrastructure, transport, industry, municipal activities and agriculture. Today, all of these heavily rely on fossil fuels for energy. The urban activities which strongly influence the City Carbon Footprint are –

4.2.1. Buildings and Construction

This sector contributes mainly to Scope 2, partially to Scope 3 and negligibly to Scope 1 emissions. Buildings are estimated to be responsible for about one-third of total global GHG emissions, mainly during their operational phase. Their emissions are estimated to grow faster than any other economic sectors, in this decade.[(Ref27)]

Infrastructure sector is a key driver for the Indian economy.[(Ref 28)] Besides other environmental impacts, buildings are responsible for 40% of national energy use as well as carbon emissions. Almost 70% of the estimated building stock that will exist by 2030 in India is yet to be built and it is important to consider this sector while moving towards carbon neutrality. They have a relatively long lifespan, and therefore, actions taken now will continue to affect their GHG emissions over the long term. A McKinsey report estimates that 25% national power demand in 2030 can be reduced by increasing energy efficiency of buildings and operations.[(Ref29)]

In a "Net zero carbon" building, the total amount of energy used by a building on an annual basis is roughly equal to the amount of renewable energy created on the site. Green Buildings and Townships should strive to provide comfort to the residents but while maintaining the natural to built environment ratio. It is necessary to avoid ultra-modernization to make buildings more sustainable.

[(Ref27)] A. Mardiana & S. Riffat (2015), Building Energy Consumption and Carbon dioxide Emissions: Threat to Climate Change. Journal of Earth Science & Climatic Change S3 : 1.
[(Ref 28)] IBEF (2019) Infrastructure Sector in India.
[(Ref 29)] TNN (2012), Nearly 70% of building stock that will be there in 2030 is yet to be built in India, The Economic Times.

Green Buildings with Net Carbon Neutral strategies and sustainable low-energy planning need to be encouraged and incentivized. In case of upcoming infrastructure projects, entire townships can be potentially built and operated as green townships to increase climate resilience and adaptation capabilities of the region (*Refer 2.2*).

Some strategies PMR should use to achieve Carbon Neutral Infrastructure are-

- Urban expansion only as planned Green Townships with Lifecycle study before permitting any large Infrastructure projects
- Design and Mandate robust building codes for energy efficiency and Renewable Energy use
- Climate Friendly Design in all upcoming constructions and promote maximum use of low carbon building materials
- Mandate Industrial and Commercial Sector to go zero carbon by investing in RE
- Encourage, provide tax exemptions and incentivize "Carbon Neutral Green Buildings" and infrastructure projects
- Score and recognize buildings with sustainable architecture as architectural heritage sites

4.2.2. Waste Management

This sector contributes mainly to Scope 3 emissions, partially to Scope 2 and minimally to Scope 1 emissions. The Waste Sector contributes to at least 4% of India's total GHG emissions. Municipal solid waste (MSW) and domestic and industrial wastewater cause high GHG emissions. Most of the current waste disposal and treatment practices often emit greenhouse gases, Methane (CH_4) and Nitrous oxide (N_2O).[(Ref30)] The MSW generation in India is increasing at a rate of 1.33% per capita per year.[(Ref31)]

For each type of waste there are various options of management, either at source, at the cluster level (e.g. gated community or municipal ward) or at the city level. Circular Economy in Waste Management is also very important in reducing the Carbon Footprint of cities in rapidly industrializing countries like India. (*Refer Annexe 2*). An 'optimal share' of methods used to manage municipal solid waste should be designed in a manner where in the organic fraction gets treated in a decentralized model, a part of the inorganic fraction is sent to the recycling stations/plants, a part of the inorganic fraction (which cannot be recycled effectively) is treated with the 'waste-to-energy' techniques and the remainder inert fraction gets land filled after proper treatment.

[(Ref30)] S. Chaturvedula, et al (2017), GHG platform India 2005-2013 State-level Estimates - 2017 Series

[(Ref31)] N. Joshi, et al. (2015), Greenhouse Gas Emissions in Present and Proposed Municipal Solid Waste Management Plans and Technologies in India : A Comparative analysis of CO_2 Equivalent Emissions from Centralized and Decentralized Municipal Solid Waste Management, Journal of Civil Engineering and Environmental Technology, 2(16) : 21-26.

HYDROGEN GENERATION FROM MUNICIPAL SOLID WASTE

Most of the components of the solid waste generated in the city can be used to generate fuel for clean transportation. Pune generates 2000 tons of waste every day. Out of which 800 ton is dry waste with upto 130 ton of thermally degradable waste (plastic, paper, leather and rubber materials) and around 100 ton is garden waste. This waste can potentially be converted into Hydrogen through the process of gasification. This waste can generate around 4 ton Hydrogen per day, sufficient for 200 fuel cell buses running 200 km/day each.

Hydrogen fuel cell buses consume Hydrogen as fuel and produce electrical energy required for their propulsion. Water vapour is generated as the only by product, making these buses practically non-polluting, clean mode of transportation. These buses also have silent and vibration free operation, which makes the journey experience more comfortable for the commuters.

Considering the fact that the corporation has to spend money on tipping fee for the waste, one can assume that this waste will be freely available for Hydrogen generation. Since the basic input for generation of Hydrogen will be available for free, the cost of running Hydrogen fuel cell buses will be cheaper than the diesel buses. Use of such buses will help in pollution reduction. Reduction in pollution is great advantage as Pune is listed amongst the top 30 cities with highest air pollution in India.

– Courtesy of Mr. Ravi Pandit and KPIT Technologies

4.2.3. Water Management

Water Pollution contributes to Scope 3 emissions, and municipal water facilities also contribute to Scope 1 and scope 2 emissions. Natural surface water and groundwater are the only available sources of water in Pune Metropolis, and hence, crucial to sustenance and survival of the region. PMR hosts 21 medium and larger Dams, 18 Catchment areas and 18 rivers and river basins. 30-40% of the city water supply is groundwater. Water management faces pressures like degraded water-quality standards, increasing demand for water and the uncertainty in weather patterns and rainfall due to Climate Change and additionally reducing emissions of greenhouse gases from water use.

Thus, there is a need to integrate energy use further into water resource management, and identify opportunities for the water sector in reducing CO_2eq emissions (*Refer Annexe 2*). Reducing water demand, increasing use of low energy techniques for water treatment, local processing of waste water and utilization of effluents for producing energy will play an important role in reducing water-related emissions.

In PMR, the Sewerage amounting 1 MLD sewage which can be potentially used for fertilization, waste-to-energy techniques, reuse and recycling, etc. Using techniques like these can reduce water pollution and emissions associated with it and increase carbon sink capacity of freshwater, simultaneously.

4.2.4. Agriculture

Agriculture plays an important role in terms of emissions as well as sequestration. This sector has maximum potential to quickly go low-carbon with proper incentives. Since more than 60 percent of India's agriculture is rain-fed, it is one of the most vulnerable sectors to climate change and needs to adapt to climate change.
Erratic monsoon rain patterns have left crops parched, jeopardizing India's nearly $370 billion agricultural sector and hundreds of millions of jobs.[(Ref32)]
To a great extent, future food security and economic independence of developing countries would depend on improving the productivity of biophysical resources through the application of sustainable production methods, by improving tolerance of crops to adverse environmental conditions and by reducing crop and post-harvest losses caused by pests and diseases. Indigenous peoples and rural communities have developed, maintained, and adapted different Eco-agriculture systems for centuries which are useful to develop viable ones now.

- Encourage Organic Farming, Nature Farming and Regenerative Agriculture (that uses organic nutrients, adopts natural methods of plant protection and relies on crop rotations, crop residues, animal manures, biological pest control, etc. to maintain soil productivity and to supply plant nutrients and to control insects, weeds and other pests.)
- Create supply chains and increase local demand for organic products
- Encourage systems for Composting or Biofuel or Biogas generation from Farm Residue to provide subsidiary income to the farmers
- Develop habitat networks in non-farmed areas to encourage biodiversity and focus on increasing soil organic carbon
- Conserve local crops and trees and using them directly in the adjacent urban areas
- Reduce land conversion to agriculture by increasing farm productivity

[(Ref32)] M. Galluccci (2015), India Drought 2015: Climate Change Is Biggest Threat To India's Economy, Modi Finance Aide Says, International Business Times

- Minimize agricultural pollution and disinvest from fertilizers and pesticides which often contain petroleum products
- Encourage and subsidize the use of solar-powered irrigation pumps and drip irrigation
- Employ effective processes for locals with indigenous sustainable practices to share their expertise with national policymakers and the international community

The effects of climate change on the 'complex and risk prone' farming systems of India will be disastrous, if 'climate-wise' development policies are not implemented with focus and regularity. Similarly, farmers must gain access to the rich scientific knowledge recommended by various research institutions/projects through efficient dissemination of the climate-smart technologies.

4.3. Re-Designing Urban Transportation for Future

Transport majorly contributes to Scope 1, increasingly to Scope 2 with transition to E-vehicles, and a little to Scope 3 emissions as well due to the infrastructure and manufacturing involved. It has been identified as one of the major contributors to GHG emissions globally, and can be one of the top contributors in urban areas. Any attempt to limit GHG emissions of a city must focus on moving away from fossil-fuel based private modes of transport, towards modes that are either zero or low emission modes measured on a per passenger km basis. The co-benefits associated with sustainable modes are improved air quality, travel safety, lower expense on commuting and democratizing citizens by slowing people down and increasing their mutual interaction. These objectives can be achieved using the following measures.

Transport and Industrial emissions together account for more than 1/4th of PMR emissions. Hence, strategies opted in these systems will contribute significantly in reducing GHG emissions, environmental degradation, air pollution, etc. PMR must achieve maximum modal share (percentage of people using a particular type of transport) of public transport and non-motorized transport to reduce its GHG emissions. Secondly, all fossil fuel powered vehicles should be phased out and replaced by E-vehicles powered with RE charging stations (*Refer 3.3.*).

In contrast, encouraging personal modes of transport will tremendously increase GHG emissions with rising economic levels. Unregulated increase in number of vehicles causes massive traffic management issues, increases pollution and also leads to congestion and traffic rule violations.

4.3.1. Improve Public transportation

- Building Metropolitan multi-modal transport hubs for ease of commute
- Increasing tracks for local train routes or Metro depending on traveling distance
- Rapid Improvement in Bus Transport by improving benchmarks, increasing frequency and number of rides, starting BRT routes and strategizing route maps for ease of access and better connectivity
- Rapid transition to E-vehicles and maximizing solar energy use at trains, metros, stations, bus-stops, street signals, etc.
- Develop Common App or Chip Cards which can be recharged and used in all public transport. Also make an integrated App which also provides optimized route and available options to the users
- Better last mile connectivity with E-rickshaws and E-cabs and flexible cycle-share plans

4.3.2. Reduce emissions from the use of private motorized vehicles

- Banning vehicles with Bharat Standard III or below
- Introducing several non-motorable zones across the city to create pedestrian zones and social spaces
- Setting up a Sustainable Transport Committee that prioritizes emission reduction
- Push for adopting E-vehicles with high efficiency and RE Charging stations to significantly reduce emissions
- Credits or discounts to regular users of Public Transport
- Parking charges or restrictions along with organized parking spaces distributed across different localities can help reducing congestion without inconveniencing private vehicle users
- Innovation and R&D in alternative fuel sources like Hydrogen fuel, Bio-CNG, etc.

Coordinated planning and implementation of urban transport programmes, eliminating overlapping functions, adequate provisioning of the budget for all modes and integration of transport modes, fare integration, research and awareness will simultaneously reduce air pollution and GHG emissions. With significant increase in Public Transport and complete shift to RE-powered E-vehicles and Efficiency measures this sector can be easily transformed into a low-carbon sector by 2030.

4.4. Enhancing Carbon Sequestration

Even after reducing Carbon Footprint drastically, some emissions due to urban activities will still persist. Hence, Carbon sequestration (Carbon Negative processes which absorb and store CO_2 from the atmosphere and water) is important to achieve true Carbon Neutrality. This can be achieved using natural sequestration methods complemented by artificial sequestration methods (*Refer 2.3.*).

Plants take in carbon dioxide for photosynthesis, and thus, act as natural sinks by removing the main GHG from the atmosphere. Trees do not exist in isolation but have a symbiotic relationship with other organisms in their native ecosystem, and thrive in their natural surroundings. Hence, ecological restoration with minimal intervention is the key to enhancing carbon sequestration capacity. In addition, destruction of forests adds to more CO_2eq emissions as the sequestered carbon gets released into the atmosphere. Over the centuries, forests have accumulated vast amounts of carbon, and our climate mitigation efforts must take the same long-term approach towards their protection.

The Global Forest Watch data reveals that 29% of the carbon stored in trees across the world is concentrated within Intact Forest Landscapes. Those in the tropics like peninsular India for 23% of the world's tree-stored carbon, despite making up just 13% of the world's total forest area. Secondly, 11% of all GHG emissions (comparable to the emissions from all of the cars and trucks on the planet) are caused by deforestation. To reach the Paris Agreement goal of reducing economy-wide emissions, countries around the world must manage forests better, and especially Intact Forest Landscapes, to both reduce emissions and increase global sinks.

On an average, carbon sequestration potential for forest per hectare is 8.44 TCO_2eq. Thus, currently, forests occupy only 12-13% of PMR area (Table 4) and hence not damaging it further is crucial for the health of the environment. These patches will act as seed banks for restoration in adjacent areas and help maintain biodiversity. If additional land is reserved across the migration corridors, watersheds and hilltops and hill-slopes in PMR jurisdiction, the sequestration also will be triple of the current potential. This will also make Pune, the first Indian city to lead by example in Biodiversity Planning.

Reserving at least 20% additional area to the existing forest cover as area for forests, urban forests and opens paces within PMR will also limit urban sprawl and misuse of land. To reduce Emission Gap, PMR may also take stewardship to protect Western Ghats and Watersheds outside its jurisdiction after reaching the ideal percentage of 33% or more forest cover of within PMR.

Table 3: Carbon Sequestration Potential of Tree Cover in PMR

Description	Units	Value
PMR Total Area	sq. km	7,256.46
PMR Forest Area	sq. km	885.39
PMR Trees and grooves	sq. km	38.59
Total	sq. km	923.97
Carbon Sequestration Potential	TCO_2 / sq. km / year	844
PMR C. sequestration Potential	TCO_2 / year	779,833.56

The biggest advantage of increasing forests is that there are so many environmental benefits from forests and watersheds that it would be worth increasing them anyway - even if they weren't so highly effective at sequestering carbon. Although, forests alone can't sequester all of the excess carbon added by burning fossil fuels, they can make a difference, especially if we help and encourage their restoration and promote stewardship of private forest lands. Patches of local ecosystem or wilderness need to be conserved and restored to sequester Carbon.

Wisely managed forests can sequester carbon and also provide a sustainable source of fuel and lumber, help clean our air and water, preserve wildlife habitat, provide recreation opportunities and preserve the beauty of trees in their natural home for generations to come. We need to prioritize preventing emissions from deforestation, and hence, offset emissions using natural carbon sequestration which is self-regulated, highly efficient, low cost and resilient to changes (only if kept intact). Following actions will play important role to prevent Environmental Degradation, loss of Biodiversity and developing Climate Resilience and Carbon Sinks in PMR.

- Conserve, Restore and protect ecological habitats in and around Pune like forests, grasslands, lakes, rivers, and wetlands to reach ideal 33% forest cover
- Implement stricter Environmental Laws and ensure existing acts like Forest Act and BDP are followed, prevent pollution and encroachment for entire PMR
- Reduce unnecessary deforestation and add forests especially in urban areas
- Increase sustainable forest management and conserve local knowledge practices
- Increase native trees and wilderness and discourage exotic tree plantations
- Conserve Watershed and improve monsoon tracking for better resilience

Chapter 5

Framework for Climate Action

Chapter 5. Framework for Climate Action

Given that urban populations in India will keep rising steadily due to migration, carbon neutrality can be achieved only by reducing per capita carbon footprint, for all activities and at all levels. Thus, it is important to set up a framework to support, encourage and establish Climate-friendly choices for individuals, households, residential societies, mohallas, wards, industries, businesses, governments, in fact, everyone. They will cumulatively make a very large impact, especially for large population centres like PMR. Building a culture of being conscious about one's Carbon Footprint is necessary to quickly go Carbon Neutral.

The Climate Action Framework (CAF) is a set of goals that must drive the decision making towards Low Carbon Development (lower carbon footprint per GDP growth) with a view to become sustainable. The Framework must prioritize significant actions required at execution levels and include guidelines for targets to be reached rather than specific actions. CAF for Indian cities should prioritize target oriented goals:

- Strict Land-use and Environmental laws and guidelines for protecting natural resources
- Reduce energy demand and increase energy efficiency in all activities, processes and systems
- Incentivize rapid transition to Renewable and Clean energy
- Mandate carbon neutral buildings
- Sustainable Transport with competent infrastructure for non-motorized and public transport
- Market incentives for Low Carbon Products and Services
- Waste management at local level with maximum 'Circular Economy' practices
- Minimum set of 'Best Practices' compulsory for all institutions with annual rewards for competitive performance
- Multiple stakeholder platforms for planning and execution of low-carbon processes and practices
  Strict action against non-compliance of CAF

5.1. Priorities for Climate Resilience and Adaptation

Impacts of Climate Change are closely inter-related with sustainability, economics, health and security. Hence, understanding these dynamics is important for increasing resilience, decreasing vulnerability of populations and adapting to the inevitable impacts of Climate Change.

Non-climatic stresses including poverty, unequal access to resources, food security, environmental degradation and risks from natural hazards negatively affect adaptation. Climate change is likely to exacerbate the degradation of resources and socio-economic pressures.[Ref 33] Thus, countries such as India with a large population dependent on climate-sensitive sectors and low adaptive capacity have to develop and implement adaptation strategies.

Efforts to cope with the impacts of climate change and attempts to promote sustainable development share common goals. Major determinants include access to resources (including information and technology), equity in the distribution of resources, stocks of human and social capital etc. These, along with abilities of decision-support mechanisms determine the capacity to cope with uncertainty.

The costs of not addressing climate change or to adapt to it are very uncertain, but their welfare consequences are enormous. Early precautionary actions on adaptation will therefore be more prudent and effective than increasing the vulnerability and stress for future generations. In a climate-challenged world, Drastic changes will lead to debt for the government. Not a viable option. Aggressive transition might be a better way. Caring and protecting other living species as well as the natural flora and fauna must become integral to human priority, to prevent catastrophic damages.

The investments needed today for timely action at various levels to prevent climate impacts, could actually save many more millions that would have to be spent for recovery from unprecedented climate-induced disasters and losses in future. Similarly, the following measures are also complementary to air pollution reduction and SDG goals.

- Get the city to make a carbon emission reduction and control plan
- Create greater awareness and support for integrated goals and their strategically planned implementation as opposed to ad hoc decision making
- Introduce important processes that require life-cycle carbon emission studies for all large infrastructure projects

Planning should focus on equity and social justice, environmental health and public infrastructure for better resilience as well as economic development. Pune needs to become a climate resilient city for a sustainable future; rather than just a smart city. Table 4 highlights the investments and benefits of Climate Change (CC) measures and their role in Sustainable Development.

[Ref33] B. Cohen (2006), Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. Technology in Society, 28(1), 63–80.

Table 4: Relation between Sustainability and Climate Action

Type	Adaptation Investments	Mitigation Investments
High CC benefits	• Vulnerability analysis • Community resilience planning • Protection for floods and sea level rise • Drought resilient crop varieties • Flood proofing roads, irrigation etc.	• Research on cost effectiveness • Social cost of carbon studies • Public awareness of • GHG emissions
Mixed CC and SD benefits	• Biodiversity corridors • Irrigation schemes • Community Forestry • Untargeted water / sanitation • Forward plans for CC related health issues Urban plans to reduce vulnerability	• Renewable energy • Reforestation • Energy Efficiency • Public Transport
Negative CC benefits	• Unsustainable groundwater use • Promoting water intensive crops	• Roads that increase • deforestation • Fossil fuel subsidies

Source: Experience from CPEIR and CCFF work in South East and South Asia

Improving resilience to the hazards associated with current and future climate variability and extremes through specific policies and programmes, individual initiatives, participatory planning processes and other community approaches can reduce vulnerability to climate change. However, Efforts to reduce vulnerability will not be sufficient to eliminate all damages associated with climate change, so Adaptation is equally important. Pune / PMR area is full of Institutions that are often impersonal to environmental priorities. PMR should mandate a minimum set of 'Best Practices' for all Educational institutions, Hospitals, Commercial complexes and public utility facilities for strict compliance, with annual rewards for competitive performance.

Last but not the least, creative and collaborative solutions need to be implemented using technology and innovative methods to bridge the Gap between Low Carbon to Zero Carbon Emissions for PMR.

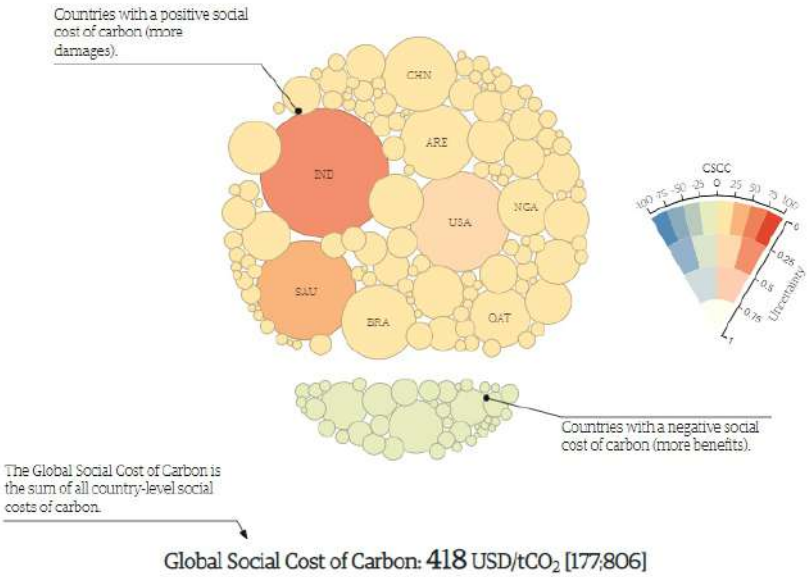
5.2. Climate Justice and Equity Imperatives

Climate Justice affirms the rights of communities dependent on natural resources for their livelihood and cultures to own and manage the same in a sustainable manner, and is opposed to the commodification of nature and its resources.[(Ref34)] The social cost of carbon (SCC) is a commonly employed metric of the expected economic damages from carbon dioxide (CO_2) emissions. USA, China and India, the top carbon emitters also face the biggest economic losses due to carbon emissions. Carbon dioxide emissions are costing the Indian economy up to $210 billion every year. It is likely to suffer highest economic damage from climate change after the US.

[(Ref34)] Bali Principles of Climate Justice, article 18, August 29, 2002

The country-level SCC for the India alone is estimated to be about $86 per tonne of CO_2.[(Ref35)]

Figure 4: Social Cost of Carbon, India



5.2.1. Unequal Climate Change Impacts

The IPCC calculates that rise in sea level would expose 13-94 million people to flooding, with about 60% of this total in South Asia. . A sea level rise of 100 cm would inundate 5,763 cubic km of India's landmass. Rise in sea temperatures and sea levels leads to loss of marine ecosystems and biodiversity, salinization, erosion and flooding and increases occurrence and intensity of storms along the entire shoreline.

The per capita availability of freshwater in India is expected to drop below 1000 cubic meters by 2025 because of population growth and climate change. River basins of Cauvery, Pennar, Mahi, Sabarmati, Tapi, Luni and few others are already water scarce. Krishna and Subarnarekha may add to the list by 2025. High population density, coastal flooding and saltwater intrusion and exposure to storm surges makes coastal river Ganga, Godavari, Krishna and Mahanadi deltas "hotspots" of climate change vulnerability.

Indian Meteorological Department declared that the storm that hit northern India in May 2018 was severe and their frequency could increase due to global warming. This is due to increase in intensity of the wind and dryness of the soil which increases the intensity of dust storms. 500Mha land is already experiencing land degradation in the Asia Pacific region. More areas all around the world are prone to desertification due to global warming.

[(Ref35)] DownToEarth Website, https://www.downtoearth.org.in/dte-infographics/social_cost_corbon/index.html

This is especially critical in countries like India where the population is not equipped or adapted to survive in water scarce situations.

Currently, the majority Indian population occupying rural areas directly depends on climate-sensitive sectors like agriculture, forests and fisheries. These sectors are heavily dependent on natural resources such as water, biodiversity, mangroves, coastal zones and grasslands. The projected climate change will have implications on food production, water supply, biodiversity and livelihoods.

5.2.2. Equity and Poverty and Climate

The current global capitalism-influenced geographical boundaries of 10% rich and 90% poor follow the outlines of history of colonialism, slavery, empire, and exploitation. The developing world is trapped into selling its resources and labour extra cheap; so that, the rich, mainly Western countries, can have fine things for the least possible price. All of the rich world, especially the western world with its additional historical responsibility, must invest and contribute more towards protecting ecological and human resources in the developing world.[(Ref36)]

The systems we have established will no longer be functional with catastrophic climate impacts. We cannot build a lasting global economy on an eroding and collapsing planet. The world must become radically more equal to slow down or prevent the climate catastrophe.

Glacial retreat, unpredictable rainfall patterns, increased flooding and drought will threaten water availability, access and quality. The degradation of water resources affects water security of the country. Salination of ground and surface water resources, especially along the coast, will contribute to water stress. The decline in water volume of rivers will add stress to intrastate water management and relations. And overuse of groundwater forces the water table lower and increases the arsenic content of groundwater.

As the majority of agriculture is rain-fed, change in monsoon will affect crop production. Increasing temperatures along with water stress are already reducing crop yield. Even under the most conservative climate change scenarios, net cereal production for south Asian countries is expected to tumble by at least 10%. At 2°C by 2050, India may need to import more than twice the amount of food-grains than would be required in the absence of climate change.

In a study by HSBC, India was listed as the most vulnerable country to Climate Change in terms of exposure to its physical impacts, sensitivity to extreme weather events, implications risks associated with energy

[(Ref36)] U. Haque (2019), (How) Climate Change is a Hangover of Colonialism, Exploitation, and Slavery, Medium.

transition and ability to respond to all these stresses. India should aim to adopt a more climate friendly and cleaner path to achieve economic development than any country has adapted in the past. India needs to simultaneously balance expanding electricity access and achieving its climate target. India needs to drastically reduce GHG emissions through climate change policies.

CLIMATE ACTION FRAMEWORK (CAF) FOR INDIAN CITIES

CAF should prioritize following goals

- ***Strict Land-use and Environmental laws and guidelines for protecting natural resources***
- ***Reduce energy demand and increase energy efficiency in all activities, processes and systems***
- ***Incentivize rapid transition to Renewable and Clean energy***
- ***Mandate carbon neutral buildings***
- ***Sustainable Transport with competent infrastructure for non-motorized and public transport***
- ***Market incentives for Low Carbon Products and Services***
- ***Waste management at local level with maximum 'Circular Economy' practices***

5.3. Role of City /State/ Centre / Political Leadership

Climate Action can only be driven by individual awareness and choice. Citizens can not only choose environmentally conscious political parties but also vote everyday as buyers and consumers. Even irrespective of climate concerns, there is a need to end the culture of limitless consumerism to save the endangered earth resources on the only planet we have. The planetary resources currently available are not sufficient for the present level of consumption, let alone to provide for an estimated increase in the world population to 10 billion along with the continuous increase in resource use.

Around the world, grassroots movements like 'Extinction Rebellion' and 'Fridays for Future' are sounding the alarm about the climate crisis, and government representatives are responding to the call. But despite commitments from the vast majority of nations to the Paris Agreement and an up-swell of action from regions, states and cities, we are still far short of what is needed. Awareness about the growing menace of global warming and the serious impacts of climate change is alarmingly low, despite many early indicators of extreme weather events around the world. There is even less clarity about what urban communities and local citizen groups can do to help.

Our civilization, and especially our country, should adopt a sustainable low carbon culture if we wish to

continue our economic growth. Some of the important measures to prepare and mobilize citizens are as follows -

- Create Awareness that every human activity creates a 'Carbon Footprint' and facilitate easy methods of measuring it at all levels
- Evolve 'Pledges' to do with less Resources and start awards and recognition for citizens accomplishing them
- Encourage innovative applications of social media to advertise the cost of not reducing energy demands and over-exploitation of resources
- Reward only performance, and not just investment in low-carbon and green measures
- Make all celebrations and festivals low-carbon and eco-friendly events
- Shift to right nutrition and encourage low-meat diet (wherever possible) to reduce Carbon Emissions from the meat industry
- Join NGOs and groups to spread awareness and increase acceptance about Climate Action

India is a developing economy with a rapidly upcoming infrastructure and dynamic economic growth. In the presence of large development gaps and incomplete markets, public policies have a key role. At the same time, social processes and institutions need to be flexible enough for learning climate mitigation, adaptation, and resilience with regard to development planning.

As experts and academicians have better knowledge and capacity to understand Climate Change dynamics, they should share their inputs and advice with policy-makers. And systems must be set to ensure that the guidelines and legalities are stringently followed. They may also contribute by helping citizens develop and understanding of cause and effect cycles and optimize at every level to reduce emissions. Involvement of young school and college student population can create lifestyle transformational changes through public awareness. NGOs and environment experts must engage the young population for desired changes.

There was an emerging consensus also on the key building blocks for Collaborative Climate Action, including:

- Robust institutional structures and policy processes to drive policy coherence and support collaboration between levels of government. Countries need strong legislation that clearly delineates authority between levels of government in order to create alignment on climate policy. Horizontal, as well as vertical, integration is key for collaborative climate action to work effectively.
- Ambitious shared climate objectives underpinned by a solid accountability framework. A key starting point for effective collaboration is the elaboration of clear national climate objectives in a way that engages subnational actors, reflects their circumstances and contributions, and builds shared ownership and accountability across tiers of government.

- Resources to match mandates at all levels of government. Achievement of national goals depends on functional subnational governments that can implement, innovate and experiment in line with national goals.
- NGOs, transnational networks and partner organizations as well as the private sector can help catalyse collaborative climate action. Filling capacity and technical gaps with NGOs and partners can help to close the implementation gap.

5.4. Participatory Governance and Oversight

Involving all stakeholders including citizens in the decision-making process is important to meet Climate Targets within the next decade. Empowering people will not only help in better implementation of policies but it will also facilitate their improvement due to continuous inputs from the users or beneficiaries. Hence, we need to enhance processes and capacities for integrated and participatory development planning.

Decision-making must involve more participatory governance to execute rules and regulations and increase cooperation from the citizens. It is important to connect innovative ideas and create platforms for collaborative learning, problem-solving and conflict resolution in achieving Climate Action. This may also be achieved with promotion, incentives, and mandates like-

- Constituting a multiple stakeholder committee including academia, experts, knowledgeable citizens, NGOs, policy-makers, and office-bearers to monitor and guide the planning and execution of low-carbon processes and practices
- Establishing Platforms for analytical assessments and informed dialogues between stakeholders will help the development of more effective interventions
- Encourage Voluntary Carbon and Energy audits in all businesses and commercial ventures to understand the energy use and then take respective actions to reduce CO_2eq emissions
- Involve and incorporate traditional and local knowledgeable people when preparing land-use and development plans for peri-urban regions. Conduct multiple Public Meetings for PMRDA master plan currently being prepared.
- Terrace farming, gardens, community farms, avenue trees and patches of wilderness also contribute to local food availability and indirectly reduce the emissions on account of transportation needs from a distant source.
- Encourage rooftop or balcony gardening and well-planned local tree-planting drives for reducing the heat-islanding effects so typical to modern cities. (This can not only help reduce the energy use for cooling and air-conditioning purposes but also maximise the potential of usable area for carbon sequestration.)

- Public Private People partnerships for rapidly achieving climate action.[Ref37]

Although Climate Finance is not within the scope of this paper, it is an urgent issue which needs to be tackled for meaningful Climate Action. (For further details, refer UNDP papers). With limited funds, it is critical that cities use their money to solve the challenges that citizens are most concerned about. Thus, efforts must begin with a comprehensive citizen engagement initiative.[Ref38]

PEOPLE'S MOVEMENT FOR BIODIVERSITY PARK (BDP) RESERVATION

The movement for Biodiversity Park (BDP) reservation is a classic example of the power of people who united to save hills and hill-slopes, the natural heritage of Pune. The city lost hill after hill in the construction boom over the last few decades, and that is why a biodiversity park (BDP) was created in 2005 as a result of strong citizens' movement with united leadership from Ms. Aneeta Gokhale Benninger, the then mayor Ms. Vandana Chavan, and many other experts, citizens and some political leaders. In 2005, the Pune municipal corporation (PMC) reserved 978 hectares of land on the hills around Pune by creating the biodiversity park (BDP) zone.

However, currently this legislation is under threat and vulnerable to non-compliance and illegal constructions. Protecting decisions made through local citizen's movement or choice should be respected when planning for any region. It is even more necessary, to have all-stakeholder participation and empower a few expert and concerned citizens to be a part of the decision-making process.

[Ref37] The Role of Public-Private Partnerships in Driving Innovation, https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2012-chapter2.pdf

[Ref38] S. Sinha (2018), Combating the challenges of urbanization in emerging markets: Lessons from India, Insights, McKinsey and Company.

Chapter 6

Case Study – PMR Carbon Neutrality

Chapter 6. Case Study – PMR Carbon Neutrality

The 'Roadmap' has explored two fundamental pathways for net carbon neutrality in Chapters 3 and 4. (Scope 1 and 2) These are independent of one another; and hence, both should be followed aggressively for achieving Net Carbon Neutrality. Each of the activities will have economic implications, but they must be executed and promoted with the help of good pragmatic planning, policy interventions, resource management and diligent monitoring. PMR has the unique advantage of still being in the expanding and developing stage. Hence getting it right from the beginning will be most cost-effective as opposed to retro-fitting that will be more expensive. PMR must prioritize Climate Smart Development for health, resilience and security reasons.

Table 5: Emissions Reduction Pathways

Sr. No.	Pathway	Description
1	Carbon mitigation	• Use Cleaner & Renewable sources of energy & reduce emissions per unit energy generation. • Increase Energy efficiency in all processes & products • Reform Urban Sectors to transition to Low Carbon Development & Economy
2	Carbon sequestration	• Absorb the unavoidable emissions with ecological restoration & increasing green cover. • Deploy novel leading edge technologies to absorb and sequester carbon dioxide from the environment.

PMRDA has defined following objectives for every function (PMRDA website) -

- To create a Premium International Investment Destination that surpasses any and every global opportunity
- To identify emerging sectors of the economy for sustainable economic growth for next 50 to 1000 years
- Spatial Planning to secure Highest Liveability Index for the citizens of PMR
- To create a Market Based Economy with a new governance model and establish PMR as a growth engine for the country and the world
- To reinforce culture and heritage in the ecological and social strata of PMR

These goals can be achieved only with 'Climate Smart Development' and 'Green Infrastructure'. That way, Pune can directly leap to a sustainable development model, without suffering the costs and consequences of business-as-usual scenario.

6.1. Estimating Emission Gaps and Cost Implications

The annual per capita emissions level in PMR can help us to identify the scale of the problem. This is already estimated to be 1.5 times more than the desired level of 2 Ton CO_2eq/year, to stay within Paris Climate targets. With current policies, emissions will increase further as the population of PMR increases. Currently, linking the increase in standard of living with rise in energy consumption, leads to GDP growth. As a growing city, increase in GDP will also proportionally require increased consumption which will affect health, pollution and productivity, if based on fossil-fuels.

Table 6: Per Capita Scope 1, 2 & 3 Emissions for PMR

Total PMR Emissions	**Carbon Footprint (tCO_2eq)**	**Percent Share in Emissions**	**Population 2019**	**Per capita Emissions (tCO_2eq/Year)**
Scope 1	6,783,870	26.03%	7,276,000	0.932
Scope 2	10,873,200	41.72%		1.494
Scope 3	8,404,227	32.24%		1.155
Total	26,061,297			3.581

Considering global trends and the domestic economy growth forecasts, one may assume that Indian economy will grow at an average compounded annual growth rate (CAGR) of 6% till 2030. Accordingly, emissions can be adjusted to factor-in the rising aspirations and changing consumption patterns of PMR population. By considering these factors, and for business as usual scenario, annual CO_2 emissions of PMR for 2030 may be expected to reach 64 million tons. The per capita emissions can almost double to 6.79 in the next 10 years unless low carbon development is adopted.

Table 7: Projections of Emissions for PMR based on Population and GDP Growth

Year	Population	Emissions (Same Standard of living) (TCO_2)	GDP increase @ 6%	Emissions adjusted to GDP (TCO_2)	Emissions Per Capita TCO_2eq
2019	7,276,000	26,061,297	1.0000	26,061,297	3.58
2025	8,472,563	30,347,162	1.4185	43,048,037	5.08
2030	9,502,054	34,034,613	1.8983	64,607,856	6.79

PMR must thus aim to reduce 80% of Scope 1 and Scope 2 emissions and 50% Scope 3 emissions of 2019 value by 2030. Even then, the total emissions will be of the order of 7733.52 $KTCO_2eq$/year.

Assuming 300% increase in sequestration potential can offset 2,021.39 $KTCO_2eq$ of the total emissions by 2030, The balance Emission Gap of 5712.14 $KTCO_2eq$ will need to be covered through artificial sequestration within PMR region or by supporting additional natural sequestration even outside PMR but in rear-by affordable land.

The proposed effort will involve significant investments for Ecological restoration of Forest Cover and Water Bodies, planning to incentivize urban forests and Tree Agriculture. Simillarly, RE industry must get major from Public as well as Private Sector funding. Although the installation costs for local distributed generation and infrastructure may be high, these can be recovered within 5-10 years depending on the scale of installed capacity. Appropriate allocation of funds and increasing efficiency in planning and implementation of policy guidelines will be very crucial. Transition to 'Low Carbon Economy' with indigenous clean RE generation actually will be very conducive to local income generation, local employment and energy independence.

Ideally, one would like to replace 100% fossil fuel by greener and non-polluting fuel and total electricity generation by renewable source. Once abundant RE availability is achieved, one can consider conversion of all applications to run on electricity and generate of all the electricity using renewable sources. Although this latter option looks interesting, it would be very difficult to change habits of the entire population. In such a scenario, the attempt would be met with considerable resistance and could be a non-starter. Hence, an alternative recommendation is suggested that may be achieved in the following way. The table below represents equivalent clean energy requirement for carbon neutral Pune at 2030 with projected "business as usual" emissions scenario.

Table 8: Equivalent Energy Requirement for PMR

Category	Per capita 2030 GDP adjusted (tCO_2eq / year)	Total emissions (tCO_2eq)	Equivalence	Cleaner energy source
Scope 1	1,769.90	16,817,710	5,304,941 Ton of fuel	Biomass, methane, battery electric vehicles, etc.
Scope 2	2,836.80	26,955,456	32,873 Million units electricity	Renewable energy mix of solar, wind, micro-hydro and biofuels
Scope 3	2,192.65	20,834,691		Increased resource utilization efficiency, sustainable material management
Total		64,607,857		

Required clean fuel quantity was calculated from weighted average, which is 3.17 kg CO_2 / kg fuel, as per Scope 1 fossil fuel emissions for PMR. Similarly, electricity requirements has been calculated considering emission factor of 0.82 kg CO_2 / unit of electricity.

6.2. Key Sectors for Carbon Emission Reduction

6.2.1. Planned Development and Urbanization

Significant amount of Infrastructure is yet to be built in PMR to meet civic demands and economic growth. Rapid urbanization being a key challenge for Indian cities, planning and infrastructure practices which support low GHG emissions and prepare the city for climate adaption, are the need of the hour. Planned urban expansion as green townships accommodating a maximum of 1,00,000 population each, which can provide comforts to the citizens without compromising the environment, will help PMR to quickly achieve carbon neutrality. Development planning and policy should focus on sustainability by increasing energy efficiency, reducing overall energy demand and reducing energy intensity of activities. Rapid transition to RE and Low Carbon Development would be critical.

Land Use Planning is a key component of Urban Planning and the ratio between natural and built-environment ought to be maintained. Decentralized Waste and Water Management will help in recycling,

reusing and processing these resources with lower energy and at lower costs. Strict Land-use norms; pollution control; protection and ecological restoration of forest cover, water bodies and watersheds and maintaining built environment to natural environment ratio will play crucial role in climate resilience and adaptation for the entire region.

6.2.2. Energy Transition

a) Solar Potential

All the buildings in PMR should have own rooftop solar power plants to satisfy part of their energy needs. But it is easier said than done. There are several limitations on whether the rooftops can be used for this purpose. The slopes on the roofs may not be favourable, the structures may be weak, the roof may have other more viable or important or attractive use, access to the roof may be a problem, it may not have shadow free area, etc. Nonetheless, one could go by the following assumptions - In industrial processes, solar energy can be used for moderate heat requirements. Solar thermal systems can very effectively and economically replace fossil-fuel based heating demands.

The easiest option for electricity generation would be rooftop and ground mounted solar photovoltaic power plants (within or outside). Parts of Pune district also has good potential for wind electricity generation. Further, kinetic energy turbines can be used to generate electricity from flowing water in canals and pipelines (Refer Chapter 4.1 and 4.2). Tapping into just 6% of the total land area for solar capacity would generate enough electricity to power PMR for the entire year. Policies on land use should factor in the above as a way of drastically reducing carbon emissions from the grid.

If one considers using 10% of the available rooftop area and 10% of the barren land area in PMR for solar photovoltaic power plant installation, one would be able to satisfy the electrical energy demand of today. To satisfy the projected electrical energy needs for 2030 with business as usual scenario, one would require much larger area, as given in the table in the section on ground mounted solar electricity potential.

Table 9: PMR Rooftop Solar Photovoltaic Energy Potential

	Area @ 10% **(sq km or million sq m)**	**MW**	**MU per year**
Ground mounted	54.54	3,408.79	4,479
PCMC Rooftop	1.77	177.27	233
PMC Rooftop	3.92	391.83	515
Total	**60.23**	**3,977.89**	**5,227**

b) Waste-to-Energy

PMRDA should initiate local Waste Management with appropriate planning in collaboration with citizens, businesses and entrepreneurships, and governance for using this resource to its maximum potential. The wastes which are generated must be properly segregated at source. Ward No 40 in Katraj, Pune city has already established this and is running the Zero Waste Circular Model successfully since 2012 with joint efforts by NGOs, residents and CSR funding.[Ref39] Such projects need to be promoted in PMR to effectively manage waste. Estimates for PMR current Waste Availability for recycling and fuel production is

Table 10: Waste-to-Energy Potential of PMR Waste

Type of Waste	Quantity	Potential
City Organic Waste	~675 - 750 TPD	Biogas, BioCNG, Composting, Biochar
Dry Recyclable Waste	~525 - 600 TPD	Recycle, Reuse or Upcycle
Inert Materials	~150 - 225 TPD	Reuse or Upcycle
Waste from farm stock	> 4.7 Lakh MT/Year	Biogas ~ 139.8 million m3 / year, Biochar
Sugarcane Waste	-	Biogas or Ethanol production
Livestock & Litter	-	Biogas

Decentralization of waste management at ward level and strict implementation of no landfill and dumping policy is a must. Today, the choice of an option is driven by convenience and economics, but lifecycle GHG emissions of the waste management process should also be a consideration. Although, provisioning for some of the following measures already exists, improvisation and increasing the efficiency and scale of these activities is crucial to make changes urgently.

6.2.3. Transport

An urgent shift to 60% or more modal share of Public and Non-motorized transport by 2030 is necessary to reduce GHG emissions. PMR should plan step-wise transition to sustainable transport and reduce private vehicles to 30% or less modal share, to prevent the public health and security issues associated with it. Optimization of Logistics and transport towards minimal use of trucks will significantly reduce the emissions within the region. This is possible with increasing local consumption, increasing railway infrastructure for commercial goods and freight, strict laws on emissions and efficiency for all vehicles, optimization of trips and routes to reduce overall travelling distance, etc.

[Ref39] P. Mastakar et al. (2019), Zero Waste Circular Model of MSWM: A Success in Ward 40, Pune, India. Metamorphosis 18(1): 36-56. –

It is also important to rapidly replace fossil-fuel powered vehicles with E-vehicles for both public as well as private transport. Good policies, incentives and finance facilities for phasing out fossil fuel-powered vehicles with E-vehicles is necessary. Last mile connectivity up to 3 km should be ensured with E-rickshaws, E-bikes and Bicycles. Multimodal transport hubs, Battery swapping stations and rechargeable card common to all modes of public transport will reduce travelling time and help users to easily commute across the region.

6.2.4. Industries and Agriculture

Industries should regularly calculate carbon, water and energy footprint and make plans to become 100% net carbon neutral by 2030. They should also invest in R&D and innovation for transition to low carbon economy with energy efficient practices and consider artificial sequestration technology for CO_2 removal from air. Majority of the agriculture should transition to organic farming and local varieties with maximal sale in nearby local markets. Use of fossil fuel-based fertilizers should be completely phased out by 2030. Schemes and incentives for Agroforestry, use of biochar or biofuel from crop residue will help in reducing carbon signature.

6.3. Capacity Building: Carbon Removal within PMR

The most effective and efficient carbon removal from the atmosphere occurs if we have patches of restored local forests and ecosystems, rather than manicured patches of plantation or garden. Conserving ecological habitats and maintaining stringent pollution and emission standards in and around PMR and for true Carbon Neutrality is the way forward.

This includes conserving the patches of forests, all water-bodies and wetlands, migration corridors and protecting traditional conservation practices and areas like ‘Sacred Groves’. The cost of preserving or restoring forests are very low, and there are minimal environmental impacts. If PMR reserves the ideal 33% of land-use for existing reserved forests and man-made forests and watersheds and catchment areas; then it will contribute largely to sequestration as well as resilience. Then the 2,394.63 sq.km. area would sequester 2,021 $KTCO_2eq$ of carbon. PMR should definitely not disturb forest cover and watersheds and let them make up at least 20% of the total area. Deforestation or disturbing natural water flows also leads to additional emissions as the sequestered carbon gets released into the atmosphere. Hence, it necessary to keep forest landscapes intact.

An additional 15% of the land should be reserved for urban forests, Agroforestry, wilderness patches and open forests and open spaces. Additionally; initiatives like urban farming, avenue trees, exposed soil cover around trees, tree plantation within premises, terrace and backyard gardens and green community practices reduce emissions and also add to the sequestration capacity of the city. Although, the proportion sounds very high, properly identified forest cover and urban forest reserves will also help in limiting the urban sprawl, which is one of the major challenges of growing urban centres. It will also help in mitigating air pollution and improving health issues.

To become net neutral PMR can also take stewardship or fund the ecological restoration of forests and water bodies outside its jurisdiction to reduce or complete the Emission gap of 5712.14 $KTCO_2eq$, assuming the Best-Case scenario. The remaining gap between emissions and sequestration will have to be addressed using scalable technology and innovation in artificial carbon sequestration. Public and Private sector should make combined investments and R&D for using negative carbon technologies to sequester CO_2 at source of emission and also from the atmosphere.

6.4. Best Case Scenario for PMR in 2030

Pune is investing resources and developing master plans and guidelines for addressing some important urban challenges. Yet the city still faces several challenges, particularly in terms of increase in environmental degradation, social segregation, and erosion of institutional capacity to manage and govern urban growth

It is misleading to promote only growth-oriented policy around GDP and expect decoupling of material and energy use. PMR can sustainably improve its human and natural assets only by favouring more comprehensive measures of societal well-being. This means adopting new systems. Hence, it requires capacity building at all levels and strategizing Climate targets with proper timelines in place and ensuring that they are met. Having streamlined Climate Action towards sustainability in PMR, the related outcomes and improvements in the economic, social and natural environment, can make PMR truly a model climate resilient city.

6.4.1. 100% Electricity from RE

With proper design considerations, the entire 42% part of the PMR emissions due to electricity consumption can be eliminated by shift to RE and Battery Storage. PMR can reduce Scope 2 emissions by opting for Rooftop Solar, Solar-Wind Farms, Micro-grids, etc. which already have market competency. Additionally, with local RE generation, all the electricity demand and surplus can be generated within PMR making it self-sustaining and energy independent.

6.4.2. Reduced direct emissions and a shift towards cleaner energy sources

Direct consumption from industrial sector, transportation and domestic fuel use currently makes up almost 26% of total emissions. For emission reductions, 70-75% modal share should be Public and Non-Motorized transport and reduction in pollution from Private vehicles by reducing their modal share to 30% or less. All Public buses should be Electricity-powered and have low emissions. Majority vehicles should shift to E-mobility with RE Charging, and hence, be cost saving. This shift from fossil fuel use to RE use will help in recycling of materials as well as positive health benefits.

6.4.3. Low-Carbon practices, processes and products in all sectors

Scope 3 emissions are about 1/3rd of the total emissions for the region. Food practices, change in Land-use, poor planning of Infrastructure, use of chemical Fertilizers, and Industry-related emissions are the major contributors. These can be reduced by low-carbon practices and achieving maximum efficiency and optimal planning to reduce demand. These are also cost-saving in addition to being less resource-intensive. Green and Low-carbon economy ensures sustainable economic development.

6.4.4. Focus on energy efficiency and conservation

This is a very important aspect, which is often missed out. It helps reduce energy demand by adopting energy efficient equipment, gadgets and processes. Energy Conservation largely contributes to reducing environmental degradation. Longer life-cycle of products and their maintenance generates opportunities for local economies.

Strict ECBC and Green Building Codes followed in all infrastructure development will provide all comforts without costing too much to environment.

6.4.5. Restored Ecosystems and increased Green cover

Ecological restoration of ecosystems like forests, water bodies and hills will play a major role in reducing emissions. And, secondly, it will prevent emissions associated with deforestation. Forest Cover and Catchment areas provide many ecological services like good air, water recharge, nutrient cycling, etc. and any damage may prove to be irreversible and damaging to Metropolis's resilience and productivity.

Additionally, to truly become Net Neutral, novel technologies that can capture carbon dioxide from the atmosphere to produce some value-added products, like biochar, can be used.

Chapter 7

A Roadmap for Carbon Neutrality by 2030

Chapter 7. A Roadmap for Carbon Neutrality by 2030

7.1. Action Agenda for Carbon Neutrality by 2030

As per World Bank reports, 90% of the urban growth is taking place in Asia and Africa. Indian cities are growing at an unprecedented rate, and large sections of the estimated 1.32 Billion population in India is constantly migrating to cities. By 2030 more than half the Indian population will be living in cities. India's "100 Smart City" initiative started in 2015 brought focus on futuristic development for improving the quality of life for its citizens. The priority was on introducing information technology and area planning for maximizing its leverage to accelerate modernization, efficiency and wealth creation.

However, there has been very little focus on making these cities sustainable for the future. In the changing environment of global warming and un-predictable climate, it is imperative to become sustainably smart. This can only be achieved by seriously reducing the Carbon footprint of cities and the nation. The development authority for PMR (PMRDA) was established in 2015 and a special purpose vehicle (SPV) approach was adopted for rapid but planned growth. Therefore, it is not too late to orient the development activity of PMR with a focus on enhancing resilience and reducing the carbon signature not only to limit the impact of climate change but also to sustain economic progress with a planned shift to low carbon economy life style.

A major modern city complex like PMR has the unique opportunity to become the first Indian 'Net Carbon Neutral' city and thereby provide leadership for all Indian smart cities. The main 'Action Agenda' to achieve the above must include –

Reduce energy demand with enhanced efficiency and reducing wastages –

- Rapid shift to renewable energy to almost completely replace the polluting fossil-fuel use and also create clean-energy abundance
- Initiate comprehensive actions for encouraging Public transport use and focus on last mile-connectivity to reduce transport sector emissions.
- Leverage Central Govt drive for electric mobility to almost eliminate use of for Petro and Diesel.
- Take-up major planned initiative for increasing natural carbon sequestration capacity matching India's NDC commitment
- Invest in Innovative R&D for 'Negative Carbon Technology' and rapidly build capacity

for removal of CO_2 from the atmosphere to effectively bridge the emission gap.

Most of the above priorities are indeed National level agenda priorities and PMR must gear-up for taking a National leadership role to provide a scalable and replicable model for all other cities.

While pragmatic and regional planning can bring out what needs to be done in a proper sequence and specific time-frame, implementation of the plan depends on a clear action-plan that is doable within desired time limits. Most such actions will have to be proactive and done with due sensitivities to the stake-holders.

7.2. Mile-stones and Targets

Essentially, the process of going Carbon Neutral starts with bending the ever-rising emissions curve downwards and changing the best practices to low-carbon economy without compromising any of the basic goals for human development and progress. The present mind-set of maximizing 'Next Quarter Profit' must change to preserving the real natural and economic assets along with addressing human aspirations for progress, stability and peace.

The mile-stones and targets of a roadmap for PMR' to achieve Carbon Neutrality by 2030 must include the following –

1. *Initiate innovative schemes for rapidly reducing overall energy demands of PMR region with energy efficiency improvements and lifestyle changes*
2. *Rapidly increase Renewable Energy (RE) capacity of PMR to drastically replace Thermal Electricity use with Solar-Wind Farms*
3. *Aggressively promote Distributed Generation*
4. *Ensure major increase in natural CO_2 sequestration capacity of PMR by 300 % by 2030 in calibrated steps*
5. *Enforce strict compliance of existing land-use laws and enact enhanced green building codes*
6. *Planned urban expansion with modular green townships each designed for low carbon footprint and smart sustainability*
7. *Modernising the Public and Non-motorized Transportation systems to discourage private vehicle use as much as possible*
8. *Aggressively introduce Electric Mobility with RE Charging (where possible) to reduce Oil-Gas consumption for transportation needs*
9. *Aggressive policy and financing by Industry-Govt. combine for Innovative R&D for technology-based sequestration at the scales required*

10. Create a culture of Climate Smart Citizenship to help reduce Indirect Emissions of the region

Taking PMR as a case study, Total CO_2 emission for the year 2018 was estimated to be about 26.061 Million-ton of CO_2eq. This comprised of 28% emissions due to direct use of Petrol, Diesel, Oil etc. within PMR [Cat-1] + 42% due to the electrical energy use within PMR [Cat-2] + 30% due to indirect emissions on account of all other CO_2eq generating activities not necessarily within PMR limit but for PMR use or consumption [Cat-3]. It is argued that by 2030, PMR can certainly reduce 80% of Cat-1 and 2 emissions (80% of 70% = 56%) and 50% of Cat-3 emissions (16%). Thus, with total 56+16= 71% emission reduction, only a balance of 29% emission of PMR at 2030 will need to be absorbed for achieving 'Net-Carbon-Neutrality'.

This should be doable if PMR can enhance its sequestration capacity of 917 MT by 300% by 2030, (in keeping with the national commitments) and bridges the remaining gap with technology assisted CO_2 removal. The technology for artificial removal of CO_2 from atmosphere is making promising progress but it can be affordable only if the emission gap is reduced drastically with serious 'decarbonizing' of all activities and changing the life-styles as fast as possible. –

What is interesting is that the roadmap proposed is also the only solution for economic sustainability for the modern human civilisation. Often such long-term wisdom is not popular in an economy focused on immediate 'next-quarter profits. But the existential threat of the earth's environment is becoming too hostile for human well-being can perhaps awaken the mankind to real priorities and accept some temporary pains for the long-term sustainable gains. History may look back on 'climate change' as the nature's way to alert the human civilisation on Earth to either drastically change the ways-of-life, or perish.

This Policy Roadmap paper calls for some fairly radical and bold actions by every citizen, Govt officials and political leaderships. This may appear too ambitious or even impossible for now, but this is a real crisis situation and must be treated as vital to National Security. Fortunately, all technology solutions are available today but mind-sets have yet to change. Annexe 1 includes further details of reforms and target markers suggested to accomplish the targets.

To limit global warming to under 1.5^0 C, annual cumulative emissions must get reduced to 80% of 2018 level in the next 10 years to 2030 and every nation must achieve net carbon neutrality by 2050.

Global Cities must take proactive initiatives to lead by example to become net carbon neutral with the help of technology and innovation.

7.3. Summary of Recommendations

1. *Total CO_2eq emission of PMR in 2018 was 26,061 KT (Kilo-Ton) and total capacity for sequestration was only 779 KT. Hence the Emission Gap was 25,281 KT.* ***For net carbon neutrality, total annual emission must be reduced to the level of total carbon sequestration and removal capacity. Bridging the gap will be the real challenge.***
2. *It is important to note that achieving* ***Carbon Neutrality for PMR by 2030 is indeed entirely doable****, if majority of citizens and political leadership can be motivated to take radically bold steps to protect the future of their children and grand-children.*
3. *First priority must be a rapid transition to Renewable Energy (RE), while drastically reducing Coal-Oil-Gas use. Global Oil industry is very powerful and they will resist change. But* ***limiting the climate impact is an absolute must now. Government subsidy to Coal-Oil sector must be stopped and funds diverted for climate mitigation & adaptation***
4. *Distributed generation of RE including roof-tops or open spaces must be boosted so that the energy transition need not hurt the economy. RE (Solar & Wind) is now very competitive today and RE with Battery storage technology can provide 24x7 clean energy abundance.* ***RE must become the 'New Oil' in the future.***
5. *For PMR, major areas for change are those within its jurisdiction. Reducing carbon emissions via maximising efficiency and minimising wastages across all sectors will be a must.* ***This can be done via people's movement and effective governance reforms.***
6. *PMRDA must maximise local distributed generation using solar, wind and biogas within its jurisdiction. This offers double benefits – replacing polluting energy with clean RE and building indigenous RE capacity for* ***increasing future energy independence.***
7. *Solar farms over just 10% of total PMR land can meet the entire electricity demand of the region with custom designed Microgrids, and advances in battery technology can provide 24x7 power.* ***This can actually create indigenous clean energy abundance and accelerate progress without any economic slow-down or any penalty to environment.***
8. ***PMRDA must evolve its own ambitious building codes and biodiversity protection norms****, ensuring 100% compliance of all new construction activities starting 2020. Violation of norms by Builders/Authorities has been the main cause of Cities in decline.*
9. ***PMR must additionally reserve 10% of its total land for ecological restoration for enhancing the region's capacity*** *for carbon sequestration. Innovative R&D for artificial sequestration and carbon removal must be initiated in collaboration of industry leaders to bridge the shortfall in natural sequestration capacity.*
10. *All new developments in PMR should be based on* ***cluster of small modular green townships, each designed to be carbon neutral within itself****. The region can thus emerge as a model for sustainable future for all Indian cities.*

11. ***All new industries in PMR region must be mandated to be carbon neutral. All existing industries must become 'net carbon neutral' by 2025.*** *This is entirely doable. PMR must enact local legislations for strict compliance with heavy penalty for defaulters.*
12. *PMR should build a cadre of trained manpower for creating the green-clean culture and* ***demonstrate that going green makes good business for future****. Hopefully, this would help in building the leadership for a sustainable eco-friendly future for all smart cities.*
13. ***Educating women and school children about the importance and means of preserving environment and limiting climate impacts*** *needs to be incentivised all over India. This can build a new generation that is much better trained to be in harmony with the natural environment.*
14. *For PMR to become 'Net-Carbon-Neutral' in 10 years, it will require several bold and coordinated transformational changes. Hence, this must have people's involvement.* ***A new "Empowered Citizen Committee" with eminent city elders must be formed*** *to advice and monitor timely execution of mile-stones along the road to carbon neutrality.*
15. *PMR must embrace the shift to* ***low-carbon economic development*** *model and demonstrate that sustainably smart development with economic progress, can go hand-in-hand with aggressive climate mitigation and adaptation actions.*
16. *PMR in collaboration with Maharashtra State and Central Government must quickly define policy priority for a set of Governance Reforms. Many of existing legislations if implemented for strict adherence, can make a good beginning.*
17. *It is very important to take a mission-mode approach with challenging time-lines and well defined mile-stones. Special powers must be created to route-out corruption and ensure maximum accountability to the public.*
18. *Political Leadership must recognize the ground-swell for climate action. Winning future elections will depend heavily on Climate Performance. Poor climate action will no longer be tolerated by the voters for whom the future depends on decisive action.*

This policy paper highlights the results of the study undertaken by the EECC team of Pune International Centre to analyse the environmental data and information available, for defining a Policy Roadmap for Pune Metropolitan Region (PMR) to become the 1st Indian 'Net-Carbon-Neutral' city.

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Annexe 1. – Roadmap Target Markers

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
1	**Initiate innovative schemes for rapidly reducing overall energy demands of PMR region with energy efficiency improvements and lifestyle changes**		
1.1	Reduce Electricity Demand by 2% from 2019 base-line	Reduce Electricity Demand by 15% from 2020 base-line	Reduce Electricity Demand by 20% from 2020 baseline
1.2	Strict 10% energy reduction mandates for all industries	15% reduction in energy demand in all MIDCs within PMR region	30% reduction in energy demand by all industries and commercial units
1.3	Ensure 100% New Buildings comply to strict energy efficiency codes	Retrofitting of 50% older buildings to comply to Energy Efficiency Codes	30 % Increase in Energy Efficiency in all PMR Infrastructure & Buildings
1.4	R& D for Low carbon technologies and practices in Cement, Steel and Manufacturing Industries – 25%	Closing or phasing out carbon intensive technologies and practices in Cement, Steel and Manufacturing Industries – 50%	Low carbon technologies and practices in Cement, Steel and Manufacturing Industries – 100%
1.5	20% of urban organic waste is treated at household, society or ward level using low carbon STPs	50% of organic waste used for production of biofuels. Set up a committee to monitor STPs across PMR.	Production of Bio-fuels and Energy from 75% organic waste produced. Ensuring 100% Low Energy STPs in all infrastructure projects
1.6	Compulsory Carbon and Energy auditing for 25% Businesses and Industries	Compulsory Carbon and Energy auditing for 50% Businesses and Industries	Compulsory Carbon and Energy auditing for 100% Businesses and Industries
2	**Rapidly increase Renewable Energy (RE) capacity of PMR to drastically replace Thermal Electricity use with Solar-Wind Farms**		
2.1	Enact Attractive policy for Rooftop Solar for all existing buildings /Mandate all new buildings to meet 50% of Electricity Needs	50% Buildings have Rooftop Solar Capacity for 50% needs (residential /Commercial/ Industry/ Institutions/Govt.)	80% or more Buildings must have adequate Rooftop Solar Capacity for all electricity needs

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
2.2	Enact attractive policy for RFT solar for all new Institutional/Com Units to reduce 33% Grid electricity use	All Industries/Com Units must reduce Grid consumption by 66 % of their respective Electricity use	100% Industrial and Commercial units to be RE-powered (mainly Solar)
2.3	Provide Subsidies for Battery Storage Installation and additional incentives for RE + Storage infrastructure development	Expand Energy Storage Capacity to make it Equivalent to Electricity Usage across PMR	Establish Two-Day/One Week Storage Capacity in PMR for minimising Thermal Grid usage to near zero
2.4	Enact Policies to make net-meter installation process quicker and simultaneously upgrading to Smart-grids	Smart-meters installed for 50% Grid users and extending Smart-grids to municipal councils and towns	100% Smart-meters installed for Grid users and 100% Net-metering for Rooftop Solar
2.5	Disincentivize Diesel Gen-Sets and Provide loans for Solar-based power-backups and Irrigation Pumps	Replace 50% Gen-Sets and Pumps with Solar Power	100% Solar-Powered Backups for all applications including A C units, Lifts and Water Pumps.
2.6	Establish Strict Environment and Reporting and Monitoring norms for establishing Solar Farms	Incentivize Private landowners to establish Solar farms to provide over 60% of Grid Loads	Solar Power Generation Capacity built across 6% of total PMR Area to meet all future needs
2.7	Set Budget to convert all Public Spaces and Government Buildings to be RE-Powered	Experts Committee should assess if 50% of the target is achieved	All Public Spaces and Facilities to provide RE-Power Abundance for all future needs
2.8	Plan installation of Solar-Wind Farms	Solar-Wind farms for Grid stabilization and for Urban demands	More than 30% of Energy demands of PMR are met by Solar Farms
3	**Aggressively promote Solar Distributed Generation**		
3.1	Encourage R&D and Innovation in micro-grids	Establish local micro-grid for 24x7 RE electricity for more select localities	Set-up Micro-grids technologies in all big infrastructure projects

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
		select localities	
3.2	-	Provide Solar installation Funding and space to weaker sections of the society	Optimized capacity of Rooftop Solar in all 10-year-old or newer buildings
3.3	Incentivize Storage along with RE more than just RE	Start building Battery storage capacity across city	Start building Two-Day Battery Storage Capacity built across the city
3.4	Incentivize Micro-grids in Rural areas	Set up Solar Micro-Grids in Rural areas along with training the locals	Maximum Off-grid generation and Solar Micro-grids in Rural Areas
3.5	All new government buildings should be mandated to use 100% RE	Retrofit or build infrastructure to make 50% Buildings Solar or RE powered	All administrative buildings completely Solar-powered, preferably off-grid
4	**Ensure major increase in natural CO2 sequestration capacity of PMR by 300 % by 2030 in calibrated steps**		
4.1	Allot 35% area to forests, urban forests, native plant gardens and open spaces in PMR Development Plan	25% of PMR area has green cover	20% of total PMR area protected as forests and an additional 15% as urban forests, urban wilderness, gardens and open spaces
4.2	Restore 10% of existing Forest Cover and monitor all areas	Restore 50% of existing Forest Cover and monitor all areas	Ecological Restoration of all natural habitats with least intervention and monitoring
4.3	Strictly protect existing trees and forest cover	50% Addition to sequestration potential	Carbon Sequestration capacity of 300% more wrt to 2019 data to 2,021.39 $KTCO_2eq$
4.4	Include Green Lines with Riparian Zones for Rivers and Streams	Strict Mapping, Assessment and monitoring	Strict mapping, Demarcation of all types of Forests and Water Bodies as Carbon Sinks

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
4.5	Establish mechanism for 5000 tree plantation per month for next 10 years on Roads and Building Premises	5,00,000 more Trees planted and monitored by citizens	Dense network of Native Plants and Wilderness Patches within Urban Infrastructure
5	**Enforce strict compliance of existing land-use laws and enact enhanced green building codes**		
5.1	Mandate ECBC and Green Building codes for all new constructions	Asses status of all old and new buildings for compliance with the Codes	Monitoring compliance with the mandatory Building Codes
5.2	Incentivize, promote and introduce funding to transition to organic farming	50% Farming is organic and incentivise sale of organic products in local markets	100% Organic and Natural farming in the region with distribution in local markets
5.3	Soil Conservation is included in all developmental planning	Planned open soil areas on all roads, around trees and in open spaces	Enhancing Soil carbon sequestration
5.4	Demarcate and protect all water bodies including primary streams	Strict jurisdiction and fines against encroachment and pollution	Mapping and conservation of Watersheds and Groundwater Recharge Areas
5.5	Strict rules and compliance with development plan when converting agricultural land to other use and pollution	Strict action against encroachment, misuse or illegal constructions and pollution	Land use Classification-Conversion of Agri. Land done carefully and pollution control prioritized
6	**Planned urban expansion with modular green townships designed for low carbon footprint and smart sustainability**		
6.1	Make policies for decentralized resource management	All Wards achieve 40% reduction in GHG emissions	All Wards achieve 80% reduction in GHG emissions
6.2	Lay strict land-use and infrastructure reforms for Green Townships	Monitor compliance by all buildings/wards to Green Building Codes	Retrofit old buildings to Low-carbon and green infrastructure

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
6.3	Train planners and officers about Green Infrastructure	Initiate yearly award best practices and best Climate friendly designs	Train planners and architects for more emphasis on resilience and adaptation
7	**Modernise Public and Non-motorized Transportation systems to discourage private vehicles**		
7.1	Set benchmarks for public transport infrastructure and Include Footpaths and Bicycle tracks in all road designs	Enhance Public Transport usage by 50% with reference to (WRT) 2019 data and Ensure Footpaths are easy to use for old people, children and specially abled people	Public and Non-motorized Transport have more than 75% Modal Share with almost 100% E-vehicles and All Roads with Continuous Footpaths and Cycle Tracks
7.2	Improve transport facilities between different modes of public transport	Improve infrastructure and facilities at multimodal transport hubs	Multi-modal Transport Hubs for railways, metros, airports and outstation travellers
7.3	Design and introduce card and mobile wallet across all modes of transport PMR and Navigation App for optimizing route	Add Facility to book in advance	Common Rechargeable Card for all Public Transport and PMR Navigation App for optimizing route
7.4	Incentivize electric autos, bikes and bicycle use	Establish only walking and cycling zones across the city	Last-mile Connectivity up to 5 km with E-autos, Bicycles, E-bicycles and E-bikes and No vehicle walkable zones
8	**Aggressively introduce Electric Mobility with RE Charging (where possible) to reduce Oil-Gas consumption for transportation needs**		
8.1	Incentivize buying Electric vehicles	50% of all vehicles are E-vehicles with RE Charging	80% of the total city vehicles are E-vehicles with RE Charging
8.2	Mandate RE Charging and Recharge points in parking slots for all new constructions	Establish RE Battery charging for all E-vehicles expected to be in operation	RE Charging at all Parking spaces, Vehicle Stands and RE Recharge Stations across the city

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
8.3	All New Buses should be Electric and Include Solar and RE Generation in Metro Planning	Make 50% Public Buses Electric-powered with RE Charging and Optimal Use of Metro Infrastructure for Solar Charging	100% Public Buses Electric -powered with RE Charging and Metro System will be 100% RE Powered
8.4	Activate and Enable plans for 25% reduction of private vehicles in PMR	Activate and Enable plans for 50% reduction of private vehicles in PMR	Private Transport discouraged to reduce its modal share to 25%
8.5	Plan Battery Swapping stations for heavy vehicles	Start building Battery Swapping Stations for Long-Distance Transport	Battery Swapping Stations for Long-Distance Transport
9	**Aggressive policy and financing by Industry-Govt. for Innovative R&D for technology-based sequestration at scales required**		
9.1	Establishing centres and institutes for research and collaboration	Carbon Credits proportional to artificial sequestration capacity	Establishment of Artificial CO_2 removal technology at MT level capacity
9.2	Minimizing release of SCLPs and GHGs at source	Minimizing release of SCLPs and GHGs at source	Minimizing release of SCLPs and GHGs at source
9.3	Primary trials for Locally customized carbon sequestration technologies	Maximize sequestration through Low carbon technologies	Conversion of waste to Biochar, Biogas , Ethanol, etc.
10	**Create a culture of Climate Smart Citizenship to help reduce Indirect Emissions of the region**		
10.1	Decentralization of waste treatment must at ward level	Recycling and Reuse of maximum materials	Cash flows following the circular economic model
10.2	All organic waste treated at source with suitable methods	100% wet organic waste is converted into biofuels or compost	100% crop waste and dry organic waste converted into biochar and biofuels.
10.3	Reduce Fossil Fuel based fertilizer	50% of all fertilizer demand reduced	No petroleum products used as fertilizers

No.	2020 Beginning	2025 Midway	2030 Actions or Targets
10.4	10% reduction in carbon emissions from water management	25% reduction in carbon emissions from water management	50% reduction in carbon emissions from water management
10.5	Encourage Low -Carbon or recycled or scrapped materials and debris recycling	Tax high- carbon material use in Construction and debris recycling	Minimize material use with designing, prefab homes, etc. and debris recycling
10.6	Strict Soil & water conservation, waste removal and Pollution control during Construction phase	Strict Soil & water conservation, waste removal and Pollution control during Construction phase	Strict Soil & water conservation, waste removal and Pollution control during Construction phase
10.7	Climate Education in School, College and University Syllabus	Encourage and Publicise Climate-friendly initiatives and actions	Create a Movement for transition to low-carbon sustainable life-style
10.8	Social Media campaigns to increase Climate Awareness and workshops for policymakers	Awarding best governance practices in Climate Action	Climate Awareness and Climate-friendly thinking in decision-making
10.9	Education about Climate Smart Development and Training of Skills required for Climate Action	Investing only in green infrastructure, green finance, Green Funds and Green Jobs and investment in R&D	Mandate all Industries and Businesses to follow environment-friendly practices and in R&D and Green innovation

Annexe 2. Notable Carbon Neutral Cities around the World

Cities are responsible for 75% of the total carbon emissions across the world, however, with conscious and effective leadership combined with active citizen awareness and participation, cities could also play a pivotal role in reducing GHG emissions. Currently, a handful of cities like Copenhegan and Melbourne are using their jurisdiction to serve as testing grounds for innovative new policies.[(Ref40)] In the past few years, such cities have radically changed their policies regulations to allow the construction of green infrastructure with a prioritized focus on increasing overall RE generation capacity and energy efficiency. Cities have also formed alliances and groups such as C40 cities[(Ref 41)], Climate Leadership Group, Carbon Neutral Cities Alliance (CNCA)[(Ref 42)] to increase the flow of ideas, information as well as funds with a common goal to reduce the city's carbon footprint. Listed below are the targets, interventions and achievements of a few cities across the world that are aggressively working towards carbon neutrality.

Copenhagen[(Ref43)]

Copenhagen, a city with a population of more than 6.02 lakhs, launched a "CPH 2025 Plan"[(Ref44)] which has 60 initiatives in 2012 with an overarching goal of making the city carbon neutral by 2025. The city administration plans to combine the forces of various sectors, data, R&D in energy and the civil society to achieve the ambitious target.

One of their primary goals it to generate 100% renewable energy with a targeted focus on wind, biomass, geothermal energy and waste. To substitute the use of fuel the city aims to heavily promote the heavily promote cyclists, new fuels like hydrogen and biofuels, strengthening the public transport system, integrating the transport system, the Congestion Mitigation Commission and by installing intelligent traffic systems.

They have also introduced a funding model for reducing the financial barriers for increased energy efficiency in the individual sectors and by employing an energy saving model in commercial and service companies. . The city is also looking at systematic consumption mapping and energy management, promoting energy efficient buildings, behavior and training and through energy efficient street lighting at the city administration front.

(Ref40) https://en.wikipedia.org
(Ref41) C40 Website: https://www.c40.org/why_cities
(Ref 42) Carbon Neutral Cities Alliance (CNCA), https://carbonneutralcities.org/.
(Ref 43) Carbon Neutral City Alliance (CNCA), Copenhagen, Denmark, https://carbonneutralcities.org/cities/copenhagen/
(Ref 44) CPH 2025 Climate Action Plan, (2012), the City of Copenhagen Technical and Environmental Administration https://kk.sites.itera.dk/apps/kk_pub2/pdf/983_jkP0ekKMyD.pdf

San Francisco (SF)[Ref45]

San Francisco is known as the city that is the leader in social, environmental and economic prosperity by setting rigorous climate goals for itself . Despite increasing economic growth and standard of living, SF has SF has also been effective in ensuring reduction in city wide carbon footprint by at least 14.5%. This is because most of the policies in San Francisco is focused on energy usage in buildings, transportation, waste, forests and municipal operations. The city also has some unique initiatives like Bus bike rack which adds more sense to the interconnectedness of transit facility.

Based on the Climate Action Framework adopted by the city SF aims to become Net Zero Emissions by 2050.[Ref 46] The pathway adopted includes for major interventions as targets for the city i.e. zero waste to landfills, 80% of trips made by low carbon transport mode, 100 % renewable energy and protection of green spaces and expanding forest cover to enhance carbon sinks capacity.

Melbourne[Ref47]

Melbourne with a population of more than 4.5 million. has adopted a five year Emission reduction Plan which includes increasing energy efficiency, encouraging rooftop solar/renewables, and upgrading street lights.

Melbourne's Pathway to Carbon Neutrality[Ref48] includes the following priorities

1. Building a low carbon scenario; the city aims at integrating the Aboriginal Knowledge, Cultural Diversity and Social Inclusion as part of their Emission reduction Plan.
2. Carbon Neutral Festivals; Melbourne takes a record of emission from premiere events and has developed a carbon ticketing option for patrons. Melbourne celebrates its culture through proper planning, and by keeping emission reduction as prior objective.
3. Green Buildings; the city administration have encouraged investments in “Zero Carbon Buildings”, energy efficient equipment's and renewable energy technologies. It also aims to develop an asset management plan for each building, and emission reductions through capital work program. Melbourne also promotes green walls in buildings.
4. Carbon Neutral goods and services; Melbourne encourages Businesses to reduce emissions by developing a supply chain workshops. It also integrates other local government works with similar organizations to amplify market demand for carbon neutral products.

[Ref45] Carbon Neutral City Alliance (CNCA), San Francisco, California, USA. https://carbonneutralcities.org/cities/san%20francisco/

[Ref 46] San Francisco Climate Action Strategy, (2013), San Francisco Department of Environment. https://sfenvironment.org/sites/default/files/fliers/files/sfe_cc_climateactionstrategyupdate2013.pdf

[Ref47] Carbon Neutral City Alliance (CNCA), Melbourne, Victoria, Australia.https://carbonneutralcities.org/cities/melbourne/

[Ref 48] Climate Change Adaptations Strategy Refresh, (2017), City of Melbourne. https://www.melbourne.vic.gov.au/sitecollectiondocuments/climate-change-adaptation-strategy-refresh-2017.pdf

5. Integrated Transport system; promoting an integrated public transport system where the options of walking, cycling and public transports are available as an option for the city. The city also promotes vehicles using zero carbon technology.
6. Reduction in Waste related emissions; introduction of new community engagement programs to discourage landfills and encourage recycling.

Pune Metropolis, being yet in the development stage, has the unique advantage of making a Climate Change Policy and plan accordingly to become one of the first Carbon Neutral City in India and put it on the World Map. When implemented successfully, it also has potential to set an example for other Indian cities to follow.

Annexe 3. Circular Economy and Climate Action

A circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling.[(Ref 49)] The main rationale behind Circular Economy (CE) is developing systems that go beyond linear "take-make-dispose" economic models and aim for closed loops of materials and energy to maintain the value of resources throughout. Since, the current valuation system does not include the true costs of raw materials, energy consumption, and environmental pressure; it poses an obstacle to circular economy activities. CE is thus a deep-rooted project with the long-term perspective of translating it into a need-based system (i.e. how can we meet a need (e.g. living) with minimum consumption of materials).

Contribution to Climate Action:

Like energy, the way we deal with materials also significantly determines the level of GHG emissions. Addressing the materials problem as a climate problem gives new Climate Solutions. It can lead to an economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times. It should be envisaged as a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows. Circular economy is thus a solution to sustainability issues and climate change.

The Circularity Gap Report, presents an articulate DISRUPT model[(Ref 50)] to give direction to the circular economy activities. It includes the following elements:

1. Design for the Future- Incorporate the use of the right materials with appropriate lifetime and capability of future use in the production of goods.
2. Incorporate Digital Technology- Employ technology to ensure optimal use of resources within the supply-chain
3. Sustain and Preserve what's already there- Maximize the lifetime of resources and products through maintenance, repairing and up gradation.
4. Rethink the Business Model- A change in the use and throw approach should be brought about by aligning businesses to create greater value and incentives.
5. Use Waste as a Resource- Reuse and Recycle waste for use in the production process.
6. Prioritize Regenerative resources- Ensure renewable, reusable, non-toxic resources are utilised as materials and energy in an efficient way

[(Ref 49)] Circular Economy Crucial for Paris Climate Goals, https://unfccc.int/news/circular-economy-crucial-for-paris-climate-goals, 2019
[(Ref 50)] The Circularity Gap Report, https://bfc732f7-80e9-4ba1-b429 f76cf51627b.filesusr.com/ugd/ad6e59_ba1e4d16c64f44fa94fbd8708eae8e34.pdf, 2019

7. Team up to create Joint Value- Bring about transparency in the supply chain to uphold the values of the circular economy.

Taking reparability, remanufacturing, and recycling into account in product design and creating the appropriate reverse cycle infrastructure can reduce the need for virgin, non-renewable resources and energy. The use of CO_2, itself, as a raw material for products is known as Carbon Capture and Utilisation (CCU). CCU can contribute to the circular economy of carbon-based materials and make a partial contribution for the transition to a low-carbon economy. However, it needs new production processes and innovation for capturing carbon and using it in materials applications.

Systematic changes in the supply-chain:

Climate mitigation actions focus on supplanting the existing energy and production systems with cleaner models. This calls for heavy investments in new systems. However, the problem of greenhouse gases emissions and excessive use of limited resources can be simultaneously addressed by making systematic changes in the supply process. An effective circular economy is one where the available resources and technology are used with a cross-sector approach so as to mitigate the need to use new sets of resources.

Such an approach not only prevents the generation of waste but also means reduced costs for industries as a result of reuse. Thus a combination of low carbon development by shifting to renewables and the improvement of resource efficiency through the circular value-chain will not only address the problem of climate change and waste but also high input costs in the long run.

In PMR, there are a host of industries which can collaborate to provide reusable resources to one another. PMR thus has tremendous potential to be a model of circular economy in the country.

Opportunities for circularity at the Household Level:

Reusing, repurposing and recycling have been traditionally ingrained in the Indian society. This can be extended further to achieve a zero-waste society by implementing infrastructural, financial and technological initiatives and other interventions, within the framework of the circular economy.

So far, waste has not been considered seriously as a sector for emission reduction or offsets. Composting is a carbon neutral process and it has the potential to replace chemical fertilizers and be used for gardening. At a household level, biogas can be used instead of LPG. Bio-char, from agricultural or garden waste, sequester carbon for long period and also improves soil quality.

Opportunities for circularity at the City/Region Level:

Plastic is an important material used in production processes in almost every industry. Its harmful effects

on the environment due to its long degradation period can be addressed by eliminating the need to create new plastic. Plastic if recycled in industries to be reused can solve the menace of micro-plastics occurring in water. Pyrolysis can help to utilize low value plastics in road constructions and for making PVC pipes. The conversion of biomass and agricultural waste to energy by fermentation, through a series of chemical reactions, can produce ethanol biofuel, another source of energy to supplant the traditional energy sources.

PMR produces about 1,200 metric tons of garbage per day. The number will increase exponentially, with increasing population, by 2030 in business-as-usual scenario. Even if we consider, better awareness on waste segregation, reduction and recycling, there will be at least 2,500 tons per day solid waste generation. Couple of plants of Waste to Energy are already installed in the region, but with very limited success. The creation of such plants needs to be undertaken through CSR and local R&D institutions, in partnership with the Municipal Corporation and supportive residential societies.

Circular Economy for Water management:

Water security is becoming a pressing concern in a climate change affected world due to the uncertainty of precipitation. For this reason, having a circular economy can prove effective to adapt to such climatic changes. Principles of Circular Economy in water management include three priorities - reducing wastage, inefficiencies, and leakages in water usage, recycling used and contaminated water, and reusing the recycled water resources. These apply to all sectors and will have different drivers and measures in rural, urban and peri-urban regions. A circular economy in water management will also provide an alternative solution for transport of freshwater, redirecting or connecting of rivers and desalination projects, which have high economic, environmental and social costs. It also increases local businesses and incomes due to integrated processes involved in the water supply chain.

A circular economy thus ensures substantial net material savings, reduced exposure to price volatility and increased economic development. It also offers opportunities for local job creation in the services sector (repair, maintenance), the manufacturing industry (local production, remanufacturing, 3D production), and the recycling industry. A circular economy that deals with materials, energy, water, food, and space intelligently is better able to withstand changes that are due to climate change. Multiple research efforts and the identification of best practice examples have shown that a transition towards the circular economy can bring about the lasting benefits of a more innovative, resilient and productive economy.

Annexe 4. Industrial Revolution 4.0 and Carbon Neutrality

These recommendations will help the environment and Climate Action and hence improve the quality of work environment and also provide a competitive advantage to the industries due to self-sufficiency. Reduction in Energy consumption will directly lead to saving the cost of energy procurement. Given the international shift towards low-carbon economy and sustainability, collaboration between PMR industries to resolve the implementation challenges will make things easier and the transition faster for economic growth.

Over the past decade an emergence of industrial revolution 4.0 is witnessed that is significantly boosting the effectiveness of manufacturing operations across the world through innovative technological advancements.[(Ref 51)] Some of these technologies such as industrial internet of things (IIOT), artificial intelligence and advanced robotics have emerged as critical technological solutions that can drastically cut down carbon emissions at a global scale.

Artificial Intelligence being one of the biggest game changers in climate mitigation, has vast potential to radically increase manufacturing efficiency across all fields. Businesses can now predict the number of goods needed for transportation to reduce the amount of waste as well as overall requirements for shipping and storage. Similarly within renewables, wind pattern can also now be predicted 36 hours ahead of time. This allows those managing the grid to make more use of renewable energy. AI has also become a critical part in urban planning for analysis of more effective district-level heating and cooling systems to reduce overall local energy consumption within the region.[(Ref52)]

Internet of Things (or IOT) is another technology that is coming up as a financial tool for climate mitigation which is why 15 percent of carbon emissions are priced and taxed today using IOT. Through aggressive expansion of sensors within IOT, carbon pricing and taxation will become far more relevant in the years to come. Automation and robotics have also become major players where, in addition to increasing productivity, robots are now starting to help manufacturers become more sustainable by reducing waste and the amount of energy used.[(Ref53)] Robots are improving the sustainable practices of manufacturers by reducing waste through extreme accuracy to minimize error. This helps the plant become more efficient in that everything that they produce is being used. Robotics are also playing a vital role in increasing sequestration capacity as machines are now being designed to plant trees at a rate of 10 times faster than a human being.

[(Ref51)] C. Ouvrard, (2018), Industry 4.0 could be a key player in mitigating climate change,Construction21 International. https://www.construction21.org/articles/h/industry-4-0-could-be-a-key-player-in-mitigating-climate-change.html
[(Ref52)] J. Rockstrom, (2018), The Fourth Industrial Revolution can lead us to a zero-carbon future - if we act now, World Economic Forum.
[(Ref53)] P. Pearce, (2019), Innovation and Technology, PLEX manufacturing website. https://www.plex.com/blogs/industry-4-0-advancements-in-manufacturing-technology.html

The process of planting these trees also costs about half of what it costs to plant a tree without the robot.

In conclusion, as innovation within technologies keep developing, we will be seeing more industries taking concrete actions towards becoming carbon neutrality. A list has been made that illustrates the actions of a few companies that have already taken strategic steps.

1. Bosch[(Ref54)]

- Bosch Global is on course to become one of the first major enterprises to become carbon neutral by 2020[(Ref 55)]. Although Bosch emits 3.3 million tonnes of CO_2, the company has already reduced its CO_2 emission by nearly 35% since 2007.
- The company also has a goal to save 1,700 GWh of energy and generate 400 GWh of its energy needs from renewable sources.
- In order to support the measures financially, the board has approved an additional annual budget of 100 million euros from the period 2018 through 2030.

2. IKEA[(Ref56)]

- IKEA Global has set an ambitious goal to reduce more GHG emissions than the entire IKEA value chain emits. The company plans to reduce its emissions from production by 80% and strive towards 100% renewable energy production by 2030, where feasible.
- By 2025 IKEA promises to phase out all coal and oil fuels used onsite in production. At the same time the company has also developed Low- Impact Glue for their wood based products which reduces their total footprint by 6%.
- IKEA also aims at increasing the energy efficiency by Installing Photovoltaic (solar) panels around 150 stores and distribution center.

3. Unilever[(Ref57)]

- Unilever Global is another organisation that has planned to become carbon positive by 2030. In 2018, Unilever had already achieved 52% per tonne CO_2 emission of production decrease compared to their 2008 baseline.
- The company has aimed to source all our electricity purchased from the grid from renewable sources and eliminate coal from our energy mix by 2020.

(Ref54) Bosch website, Carbon neutral research, production, and administration. https://www.bosch.com/company/sustainability/environment/

(Ref55) Bosch Press release, (2019), Bosch to be carbon neutral worldwide by 2020. https://www.bosch-presse.de/pressportal/de/en/climate-action-bosch-to-be-carbon-neutral-world-wide-by-2020-188800.html

(Ref56) IKEA Website, (2018), https://newsroom.inter.ikea.com/news/ikea-accelerates-movement-to-become-climate-positive--committing-to-reduce-absolute-greenhouse-gas-e/s/45bfcf5a-742b-4bde-8744-5ca9de43c0b8

(Ref57) Unilever Website, How we're becoming carbon positive in our operations https://www.unilever.com/sustainable-living/reducing-environmental-impact/greenhouse-gases/how-were-becoming-carbon-positive-in-our- operations/

- By 2030, the plan to source 100% of our energy across all their operations from renewable sources and also make the surplus available to the markets and communities where we operate by 2030.

4. Mahindra and Mahindra (M&M)[(Ref58)]

- Mahindra has been the first Indian company to sign on to the global EP 100 initiative, committing to keep operational energy consumption at its 2009 levels while doubling production by 2030 (The Climate Group 2016).
- As part of their sustainability strategy, M&M have committed to 25% emission reduction by 2019.
- In 2018 the total Investments on Environmental Interventions was worth INR 288.47 million which were directed in different sustainability schemes covering important areas such as external certification on migration systems, renewable energy certificates, water quality monitoring, Air quality monitoring, waste disposal and treatment and wind power.

[(Ref58)] Mahindra sustainability Report (2018), https://www.mahindra.com/resources/pdf/sustainability/Mahindra-Sustainability-Report-2017-18.pdf

Annexe 5. Government Legislation supportive to Climate Action

Certain governance instruments at the Local (PMC, PCMC, Panchayat), State (Maharashtra) and National (India) are already in place to address the issue of Climate Change in the country and to adhere to the Nationally Determined Contributions (NDCs) of India under the Paris Agreement. Most of these instruments, if enforced strictly along with similar such orders, can equip governments at all levels to effectively implement climate change adaptation and mitigation programs. Especially, PMRDA as a Special Purpose Vehicle can use these as a support their Climate Action Agenda in developing the region as a model for the country.

To address climate change, local governments like the Gram Panchayats have the authority to legislate on matters related to land improvement, social forestry and non-conventional energy sources according to the **Eleventh Schedule** of the Constitution of India. The **Twelfth Schedule** of the Constitution permits urban local bodies like Municipal Corporations to legislate on matters related to land use, urban planning, solid waste management, urban forestry, protection of environment and promotion of ecological aspects. Consequently, the **National Green Tribunal (NGT) order of 2013** has also directed civic authorities to form a tree authority, of seven corporators (preferably graduates from the Science stream) and seven nominated members from NGOs. Apart from that PMC has two important initiatives that, if promoted and intensified are beneficial in mitigating the effects of climate change. The **Green Rating System** (Indian Green Building Council, GRIHA and SVAGRIHA Rating) for commercial building with spaces greater than 2500 sq.m. is one, while achieving 15-20% of energy generation through rooftop solar in Aundh,

Baner and Balewadi is another. However the Green Rating System needs to be made mandatory for any new construction, be it commercial or residential to achieve the 2030 emission reduction targets for PMR. Solar electrification needs to be intensified in every part of the city and PMR by promoting mini-grids and net-metering.

At the State level, to tackle issues of vulnerable areas like agriculture, coastal cities etc. by securing finance for environmental protection from private and international agencies, formulating adaptation and mitigation policies and by undertaking in-depth research on climate change, **the Maharashtra Action Plan on Climate Change** was framed in 2018. The **Maharashtra (Urban Areas) Protection and Preservation of Trees Rules, 2009** directed the creation of a tree authority to document and preserve the tree cover in urban areas and exercise strict control over the felling of trees. Apart from that, the **Maharashtra Energy Conservation Policy (Mahaurja), 2017** seeks to enforce the **'National Energy Conservation Policy, 2001'**, sets the target of saving 1000 MW of energy in the state from 2017-2018 to 2021-2022 and advocates

I) The National Mission on Strategic Knowledge for Climate Change aims to create knowledge systems and networks for identifying, formulating, planning and implementing policy driven actions while maintaining the necessary economic growth. The mission however does not incorporate scientific policies and the necessity of technological inputs for climate change.

j) The Forest Conservation Act, 1980, calls for the constitution of an advisory committee for matters related to conservation of forests and restricts the use of forest land for non-forest purpose without permission. It also has the power to prosecute government authorities and departments if they work against forest conservation.

k) The National Green Tribunal Act, 2010, was enforced with the view of ensuring effective and speedy disposal of cases relating to environment protection and conservation of forests and other natural resources by establishing the Tribunal. However, the fact that the order of NGT can be challenged in the Supreme Court makes its powers mere nominal.

The literature on climate change with the government is extensive with a number of guidelines and missions. However strict regulations followed by punitive actions for aggravating the problem do not still exist. Climate Change although a global phenomenon requires concerted efforts at the regional level to make a significant impact. The government policies that are in place today have tremendous potential to help the country to achieve the Paris commitment of limiting the global average temperature to 1.5^{o}C, however the implementation is seriously lacking. `Climate Change is inevitable and will have a detrimental impact on the future generations. For this the government needs to lead its various bodies, the private players and the civil society through stringent policies for mitigation.

Non-Conventional Sources of energy, social forestry and land improvement are the issues mentioned under the Schedule XI of the Constitution that provide local rural governments jurisdiction over issues necessary to combat climate change. This forms an important starting point for engaging the majority of the governance area in the country in the fight against climate change. At the National level, a plethora of policies are in place for urban planning, renewable energy, environment and climate change. Of those, the most important is the **National Environment Policy, 2006** that has been adopted with a view of creating legislations, programs and projects for environmental conservation by fostering partnerships among the various stakeholders to conserve and provide a sustainable livelihood for those living in a particular habitat. This act forms the basis for taking measures for climate change mitigation. Other set of guidelines and missions that have the potential to add to the cause include:

a) **The Energy Conservation Building Code, 2017** that prescribes energy performance standards for new commercial buildings to be constructed in the country.

b) **The National Energy Conservation Act, 2001**, seeks to establish the Bureau of Energy Efficiency and provides powers to the state government to facilitate the efficient use of energy and conservation. These

powers include amending energy conservation building codes to suit the regional and local climatic conditions, designate an authority within the state to enforce the act and constituting the State Energy Conservation Fund for the efficient use of energy and its conservation within the state.

c) **The National Mission on Sustainability Habitat** aims to make cities sustainable through improvements in energy efficiency in buildings, management of solid waste and shift to public transport.

d) **The National Policy on Biofuels** has been framed with the aim of finding an easily available substitute in biofuels for petrol and diesel and ensuring that a minimum level of biofuels becomes readily available in the market.

e) **The Energy Conservation Guidelines for Industries** have been framed with the aim to manage energy consumption by standardizing the energy performance values of various energy consuming equipment and systems deployed for the manufacturing process.

f) **The National Mission for Enhanced Energy Efficiency (NMEEE)** consists of 4 initiatives: i) PAT (Perform Achieve and Trade) ii) EEFP (Energy Efficiency Financing Platform) iii) MTEE (Market Transformation for Energy Efficiency) iv) FEEED (Framework for Energy Efficient Economic Development). However, only one initiative out of 4 concerns the household sector.

g) **The Bharat Stage Emission Standards** that are based on the European emission standards are issued with the intention of regulating the output of air pollutants from motor vehicles. However incentives to shift to either public transport or electric cars is still lacking in the country.

h) Through the **Standards and Labelling system** of BEE the government encourages consumers to make informed choices when it comes to purchasing high energy electrical appliances. At the same time, the practice of calculating and mentioning the carbon footprint of every commodity can hep consumers make informed choices.

Annexe 6. Case for 24 x 7 RE Supply

For PMR to transition towards a 24 x 7 RE supply a shift towards distribution generation becomes critical where a large number of independent generation facilities provide electricity at an individual level or within a cluster throughout the region. Such a system has immense potential to drastically reduce CO_2 emissions by increasing efficiency and reducing dependency on the thermal powered grid.

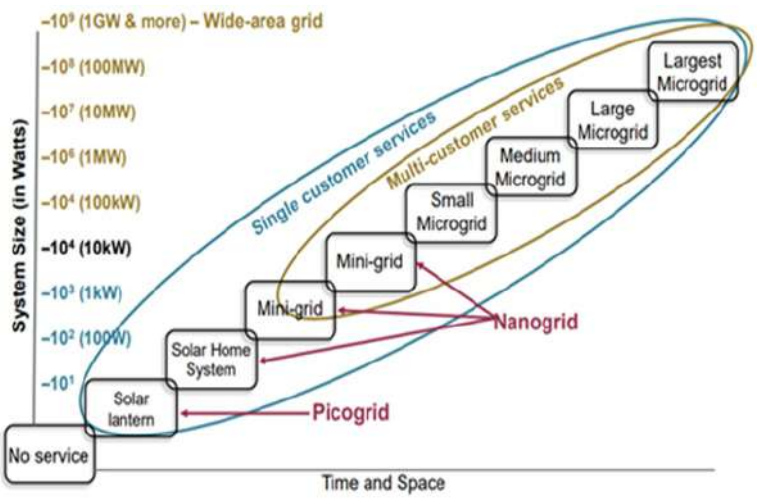
Based on an analysis, a replacement of 75% supply from Thermal power grid to RE can over 10 years in PMR can reduce CO_2 emissions by almost 7 million TCO_2 per year by 2030 from the 10 million TCO_2 per year baseline that is emitted today.

Table 11: Estimates of Thermal and RE Supply[(Ref 59)]

Year	Cumulative Thermal Supply (MU)	Cumulative RE Supply (MU)	Net Annual Emissions
2024 - 2025	9945	3315	8,154,900
2029 - 2030	3315	9945	2,718,300

Such a distributed generation system will consist of a range of mini and micro grids apart from independent household systems. A Mini Grid is defined as a system having a RE based electricity generator. Such systems generally operate in isolation to the electricity networks of the DISCOM grid (standalone), but can also interconnect with the grid to exchange power.

Figure 5: System sizes against time and space



[(Ref 59)] MahaGenco Website https://www.mahagenco.in/index.php/generation/articles

The generator of a mini or micro grid can be powered by RE sources such as solar, biomass, wind, small hydro or other notified sources and can have diesel-based generator as a backup. Hybrid systems using a combination of resources like those that of solar-wind, solar-biomass, solar-hydro etc. can also be deployed to improve system reliability and for back up.[(Ref60)(Ref61)]

The primary advantage for distributed system is that small renewable sites generate significantly less power and also bypass the need for costly transmission network investments. Eliminating the need for new transmission infrastructure greatly decreases the cost and increases the speed of new development.

Apart from that, distributed generation is that renewable generation facilities are built in an expedited time frame compared to traditional plants. As the Energy Information Agency (EIA) expects global electricity consumption to grow by roughly 50% by 2040 as seen in the chart below, the ability to quickly and cost-effectively build new generation facilities will be indispensable in the future.

Lastly, traditional generation relies upon a limited number of power production facilities which often have dated backup generators in times of emergency. With significant reliance upon a limited number of generation nodes that may have shoddy emergency capabilities, the macro grid risks widespread consequences should significant problems such as floods or hurricanes arise at even a small number of locations. Distributed generation helps to curb this issue by having a far more widespread generation profile and hence would have play an important role to provide enhanced stability and resiliency in the near future.

Storage Technology

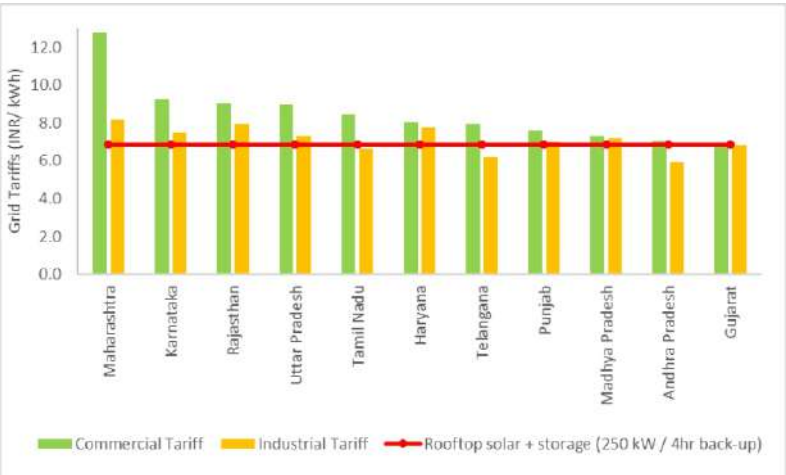
However, a distribution system without storage technology to capture energy would not be possible considering the intermittency of solar or wind. To tackle this issue, what must run parallel to increasing investment in solar capacity is strategically flooding the system with energy storage with residential as well as commercial areas.

Currently, battery technology is the most popular option primarily due to its flexibility and also drop in the cost because of increased demand where Li- ion battery technology has become a front runner in the battery race. In fact, many western countries have adopted Li-ion batteries as a backup technology for their renewable systems where several factors have contributed to the rapid uptake of residential energy-storage systems:

(Ref60) Raghav Pachouri et al (2019), Exploring Electricity Supply-Mix Scenarios to 2030.
(Ref 61) Wind power engineering website: https://www.windpowerengineering.com/the-rise-of-wind-power-what-to-expect-in-2019/

Falling costs: From 2012 to 2017, the per-kilowatt-hour cost of a residential energy storage system decreased by more than 15 percent per year. As per JMK Research, at present, a 1 MW rooftop/ onsite solar plant with 250 kW of battery storage (4 hr backup), is already a viable solution for commercial consumers across key states in India. For industrial consumers, solar with storage is feasible in seven key states except, Tamil Nadu, Andhra Pradesh, and Telangana.

Figure 6: Viability of rooftop/ onsite solar system with storage in India



Increasing disruption risk: Every time a major hurricane or storm hits, battery-installation rates increase sharply. As a result, storm-affected states like Florida and Texas have seen accelerating residential battery adoption. Similarly, homeowners in wildfire-prone areas of California have begun to install home batteries for reliability.

Utility rate structures: Some utilities set prices based on time of use (TOU), such that power prices vary depending on the time of day. Battery-equipped households can now use energy storage to minimize how much power they consume during periods of peak prices.

Solar-plus-storage benefits: Integrated installations of solar and storage equipment cost less and allow even more flexibility in adjusting demand and supply to reflect market rates, potentially reducing the cost of a battery system by more than 25 percent compared with a stand-alone storage pack.

With upcoming battery breakthroughs, there is massive potential for further disruption taking place in the battery storage market. For instance, recently a solid state battery which uses sulfide superionic conductors was invented which could operate at super capacitor levels to completely charge or discharge in just seven minutes - making it ideal for cars. Similarly, the recently awarded Nobel Laureate John Goodenough also invented a solid state glass battery that is non-combustible and has a long cycle life (battery life) with a high volumetric energy density and fast rates of charge and discharge.

Annexe 7. Hydrogen Fuel

Hydrogen fuel cell technology transportation has recently emerged as a highly viable alternative that can easily complement EVs within PMR. In fact, taking cue from California which has invested over 900 million$ to jumpstart hydrogen fuel cell in the state, PMR also has the potential to pioneer fuel cell transportation within Maharashtra

The application scope of fuel cells is expansive, including material handling, portable, stationary, power backup and transport. Fuel cells have myriad advantages over combustion-based devices, with over 60 percent efficiency in the conversion of the fuel's chemical energy to electrical energy.

One of the viable ways that PMR can transition towards harnessing fuel cell technology is by first prioritizing the transition of public vehicle. For instance, PMRDA can incentivize bus fleets travelling between Pune-Mumbai corridor or Pune-Nagpur corridor to run on hydrogen fuel cells as they have twice as much range as battery electric buses. They can also refuel quickly, and they are easier to scale up because one hydrogen refueling station can handle larger volume than a single charging post; but the purchase price is still very high.

Given that that hydrogen fuel cell conversion emits only water and heat, it emits zero carbon emissions. Fuel cells vehicles exhibit higher efficiency compared to combustion-powered vehicles, as they generate no tailpipe emissions. To put that in perspective, 1 gal of gasoline has about the same amount of energy as 1 kg of hydrogen. Most fuel cell electric cars carry about 5 kg to 6 kg of hydrogen but go twice the distance of a modern internal combustion engine car with equivalent gas in the tank, which works out to a gasoline-per-gallon equivalent between Rs.350 and Rs.420. Hydrogen fuel cell cars now average between 502 km and 612 km in range.

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